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ABSTRACT

The ocean affects all of our lives. Therefore, awareness of and information about the interconnections between humans and oceans are prerequisites to making sound decisions for the future. Project ORCA (Ocean Related Curriculum Activities) has developed interdisciplinary curriculum materials designed to meet the needs of students and teachers living in Washington State. Each activity packet provides the teacher with a set of lessons dealing with a particular topic related to the oceans. Included are student worksheets, lesson plans, a vocabulary list, and a bibliography. This activity packet is designed to introduce senior high school students to some basic concepts of marsh, estuary and wetland ecology. Each of these habitats comprise an important link in the cycling of water through a watershed. A review of the watercycle and an introduction to the classification of watershed systems sets the stage for further investigation into each habitat. Field experiences focus learning on very specific features of the wetlands and marshes. Data for a site is collected through scientific analysis and an inventory of the hydrology, vegetation and wildlife, and the visual, cultural, economic, and educational values for that site. (TW)

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MARSHES, ESTUARIES AND WETLANDS

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ORCA

OCEAN RELATED CURRICULUM ACTIVITIES

PACIFIC SCIENCE CENTER / SEA GRANT MARINE EDUCATION PROJECT

Andrea Marrett, Manager
Andrea Marrett, Writer
Susan Lundstedt, Illustrator

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ORCA PUBLICATIONS

ELEMENTARY

High Tide, Low Tide (4th Grade)
Life Cycle of the Salmon (3rd - 4th Grade)
Waterbirds (4th - 5th Grade)
Whales (4th - 6th Grade)

JUNIOR HIGH

Beaches
Beach Profiles and Transects
Early Fishing Peoples of Puget Sound
Energy from the Sea
Literature and the Sea
Tides
Tools of Oceanography

SENIOR HIGH

American Poetry and the Sea
Marine Biology Activities
Marine Biology Field Trip Sites
Marshes, Estuaries and Wetlands
Squalls on Nisqually: A Simulation Game

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PROJECT ORCA

The ocean? It's 2 miles away; it's 200 miles away; it's 2000 miles away. What does it matter to me? For those students who live close to the ocean, a lake or a stream, the effect of water might be more obvious. For the student who lives on a wheat farm in the arid inlands, the word ocean is remote. It may conjure up images of surf, sand and sea gulls, experiences far removed from their daily lives; or it may have no meaning at all. Yet for that same youngster, the reality of the price of oversea wheat shipments or fuel costs for machinery are very real. The understanding of weather and its effects on the success or failure of crops is a basic fact of everyday life. The need for students to associate these daily problems with the influence of the marine environment exists. It requires exposure to ideas, concepts, skills and problem solving methods on the part of the youngsters. It also requires materials and resources on the part of our educators.

The goals of ORCA (Ocean Related Curriculum Activities) are: 1) to develop a basic awareness of ways in which water influences and determines the lives and environments of all living things; and 2) to develop an appreciation of the relationship of water to the study of the natural sciences, social sciences, humanities and the quality of life.

ORCA attempts to reach these goals by: 1) developing interdisciplinary curriculum materials designed to meet the needs of students and teachers living in Washington State, 2) developing a marine resource center, and 3) providing advisory services for marine educators. In conjunction with these efforts, ORCA is coordinating communication among educators throughout the state and the rest of the nation.

The curriculum materials are developed to be used in many areas including the traditional science fields. They consist of activity packets which fit existing curricula and state educational goals and are designed for use as either a unit or as individual activities.

The ocean affects all our lives and we need to be aware and informed of the interconnections if we are to make sound decisions for the future of the earth, the ocean and our own well being. We hope that through Project ORCA, teachers will be encouraged to work together to help students understand and appreciate the ocean and the world of water as a part of our daily existence.

ACKNOWLEDGEMENTS

The senior high series of ORCA (Ocean Related Curriculum Activities) is the product of a cooperative effort between many people and organizations. The primary responsibility for the program belongs to the Pacific Science Center, where the materials were developed. Financial assistance and technical support were provided by the National Oceanic and Atmospheric Administration (N.O.A.A.) Sea Grant, held by the University of Washington.

TRIAL TEACHERS

Trial teachers help us by testing the materials with students in the classroom and by reading, evaluating and offering suggestions for more effective curriculum. The teachers who gave their time, effort and advice were:

Bill Bond
Bill Brockman
Dave Brubaker
Cecelia Moore

John Pauls
Shirley Pauls
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ADVISORY COMMITTEES

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Levon Balzer, Ph.D., Dean of Instruction, Seattle Pacific University
Helen Frizzell, Teacher, Northshore School District
Charles Hardy, Coordinator, Math and Science, Highline School District
David Kennedy, Supervisor of Science, Environmental and Marine Education, Office of the Superintendent of Public Instruction
Roger Olstad, Ph.D., Associate Dean of Graduate Studies, University of Washington, Committee Chairperson
Alice Romero, Teacher, West Seattle High School, Seattle School District
William Stevenson, Superintendent, Shoreline School District
Mark Terry, Associate Director, Environment, The Northwest School of the Arts, Humanities, and the Environment, Seattle

STAFF

Finally, the production of the senior high series could only occur with the immense help of staff members who were instrumental in creating, developing and supporting this project.

As one of the curriculum writers for the senior high series, I can truly appreciate the efforts of the other writers:

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MARSHES, ESTUARIES AND WETLANDS

ABSTRACT: Marshes, Estuaries and Wetlands is an activity packet that introduces high school students to some basic concepts of marsh, estuary and wetland ecology. Each of these habitats comprise an important link in the cycling of water through a watershed. A review of the watercycle and an introduction to the classification of watershed systems sets the stage for further investigation into each habitat. A slide show gives a visual overview of parts of the watershed while lab and field experiences focus learning on very specific features of the wetlands and marshes. Data for a site is collected through scientific analysis and an inventory of the hydrology, vegetation and wildlife, and the visual, cutural, economic, and educational values for that site. Such data is useful in land use planning for the future.

SUBJECT AREAS: Science, Biology, Environmental Education, Social Studies, Chemistry

GRADE LEVELS: Senior High School

WRITTEN BY: Andrea Marrett

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ACTIVITY 1: WATERSHEDS AND WETLANDS SYSTEMS (3-4 DAYS)

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The watershed is the area receiving precipitation and conducting water drainage in the continual recycling of water. It is an important ecosystem which humans have classified in order to understand it better. In this activity students will review the water cycle, and locate major watershed in Puget Sound. A classification system for watershed will be introduced with students learning the appropriate vocabulary. A slide show accompanies this activity.

ACTIVITY 2: ESTUARIES AND SALT MARSHES (7 DAYS)

41

This activity examines estuaries and salt marshes more closely. Students will learn about the different types of estuaries and how they were formed. Lab experiences focus attention on important aspects of the salt marsh - estuary habitat. The students will become familiar enough with the ecology of a salt marsh to construct the food web of that habitat.

ACTIVITY 3: FIELD INVESTIGATIONS AND WETLAND INVENTORY (2-10 DAYS)

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Learning about both salt marshes and fresh water wetlands requires observing them in person. Wetlands are frequently found close to schools and are excellent field trip sites. The series of field activities and scientific analyses are designed to help students observe the wetland more carefully and begin to understand this habitat. The Wetlands Inventory is a modified survey instrument modeled after the one used by King County Resource Planning in their survey of the wetlands of King County. Data obtained from such surveys are useful in planning for future growth.

EVALUATION, VOCABULARY, BIBLIOGRAPHY

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ACTIVITY 1:
WATERSHEDS AND WETLANDS SYSTEMS
(3-4 DAYS)

ACTIVITY 1: WATERSHEDS AND WETLANDS SYSTEMS (3-4 DAYS)

CONCEPTS:

1. The watershed is the area receiving precipitation and conducting water drainage in the hydrologic cycle and plays an important function in the total ecosystem.
2. The watershed is a series of connected water course systems that complete a drainage pattern for one basin.
3. The water course systems have been classified into wetland systems, subsystems, classes and defined as habitats by the existing (present) biotic and abiotic factors.

OBJECTIVES:

The learner will demonstrate his/her abilities to:

1. describe the hydrologic cycle.
2. name and describe components (sections) of a watershed and of the wetlands.
3. explain the location and function of the components of the watershed.
4. define what a watershed is.

TEACHER PREPARATION:

1. Read the background teacher information and student readings:
    "The Water Cycle"
    "Marshes, Estuaries and Wetlands"
2. Preview the slide show "Wetlands: A Watershed Perspective."
3. Reproduce class sets of:
    "Marshes, Estuaries and Wetlands"
    "Puget Sound Regional Topographic Map"
    "Evaluation"
4. Optional. Make transparency or student handouts of the teacher information sheet, "The Water Cycle."

MATERIALS:

1. Class sets of:
    "Marshes, Estuaries and Wetlands"
    "Puget Sound Regional Topographic Map"
    "Evaluation"
2. Optional. Colored pens or pencils.
3. Slide projector, screen and carousel

PROCEDURES:

The Water Cycle - A Review Activity

1. The water cycle -- the cycling of water in the ecosystem, appears to be a simple concept, yet a review of the basic process is necessary to prepare students to understand the critical functions wetlands perform in the total ecosystem.

2. On paper, have the students briefly diagram the flow of water in the hydrologic or water cycle. This should be a review of previously acquired knowledge, but if not, help them by asking such questions as: "Where does water go when it rains? "Where do the rains come from? "How does water enter and leave lakes? Ponds? Streams?"

3. The teacher information sheet, "The Water Cycle" can be used as a transparency or a hand-out to promote an under-

standing of the cyclic flow of water through the environment. If surface water run-off and groundwater recharge or seepage are not brought up by the students in this diagramming activity, introduce the concept and explain how this very important part of the water cycle functions in the watershed.

Defining Watersheds

4. This section encourages students to expand their understanding of what a watershed is and the location and function of each of the components of the watershed.

5. Hand out the "Puget Sound Regional Topographic Maps" to the students. Have them locate the mouth of one of the major rivers in the Puget Sound and trace back to its source with dashes. Use arrows to show the direction of the flow of water. Tributaries that flow in the river should also be marked with the dashes and arrows.

6. When completed, have the students block in the area showing the river areas.

7. Using a different colored pen or pencil, have the students do the same activity on the river to the north and south of their chosen river.

8. When completed, have the students block in the area showing the area of the first river. The lines should not overlap either of the other two areas but have a common boundary between adjacent systems along the crest of invervening ridges. This represents the drainage area of the river. It is the watershed. All of the water bodies within this blocked-in area belong to the same watershed.

9. Hand out the student reading "Marshes, Estuaries and Wetlands." This reading reviews the water cycle and watershed concepts and introduces students to the classification of wetlands.

10. Refer back to the previous activity and to the descriptions of the Fish and Wildlife Service for each component of the water shed. Have the students place on their map an X that would best suggest where the group (of which they were a member) would most likely be located. Ask them if there might be several locations within that watershed where their group might be located. Ask them to mark additional locations. Students may need help with this activity.

Wetlands: A Watershed Perspective

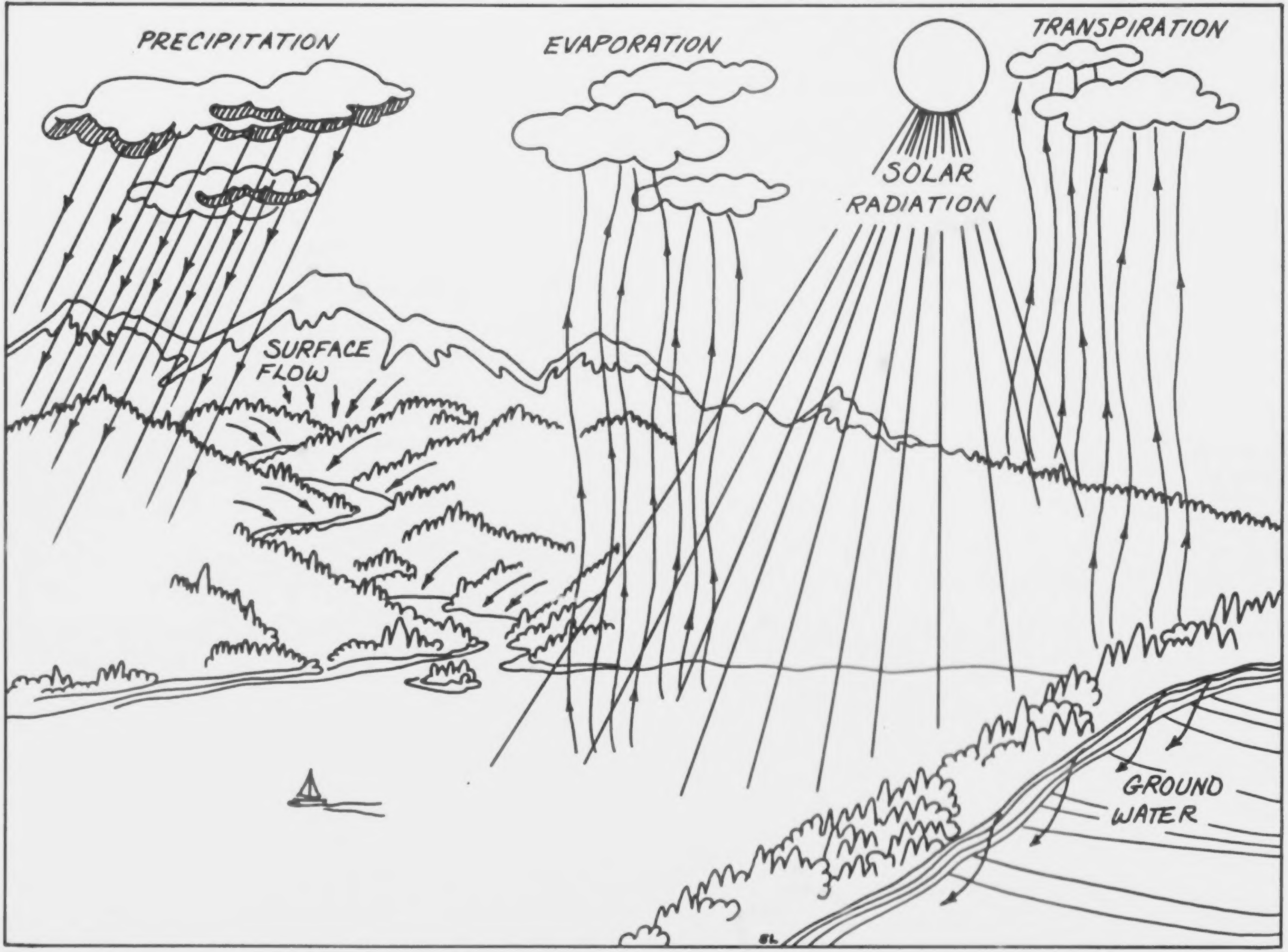
11. Show the slide show "Wetlands: A Watershed Perspective." The slide show is in 3 parts. The first is an overview

of watersheds and review of each of their components (sections). The second part focuses on the salt water wetlands and the third emphasizes the function and need for the often ignored fresh water wetlands.

12. The wetlands play an important function within the ecosystem. They retain and detain flood waters, they act as nutrient storage reservoirs, they represent one of the most productive natural environments in the world ecosystems and they are a significant habitat for birds, mammals, reptiles and amphibians. In addition, many of the wetlands have been attractive places for human alteration and occupation for farming, pasture lands, industry and city development.

Evaluation

13. The "Evaluation" is intended to encourage student recall of new concepts and to extend their thinking about wetlands and watersheds. Have students complete the evaluation and follow up with a review discussion.


PRECIPITATION
EVAPORATION
TRANSPIRATION
SOLAR RADIATION
SURFACE FLOW
GROUND WATER
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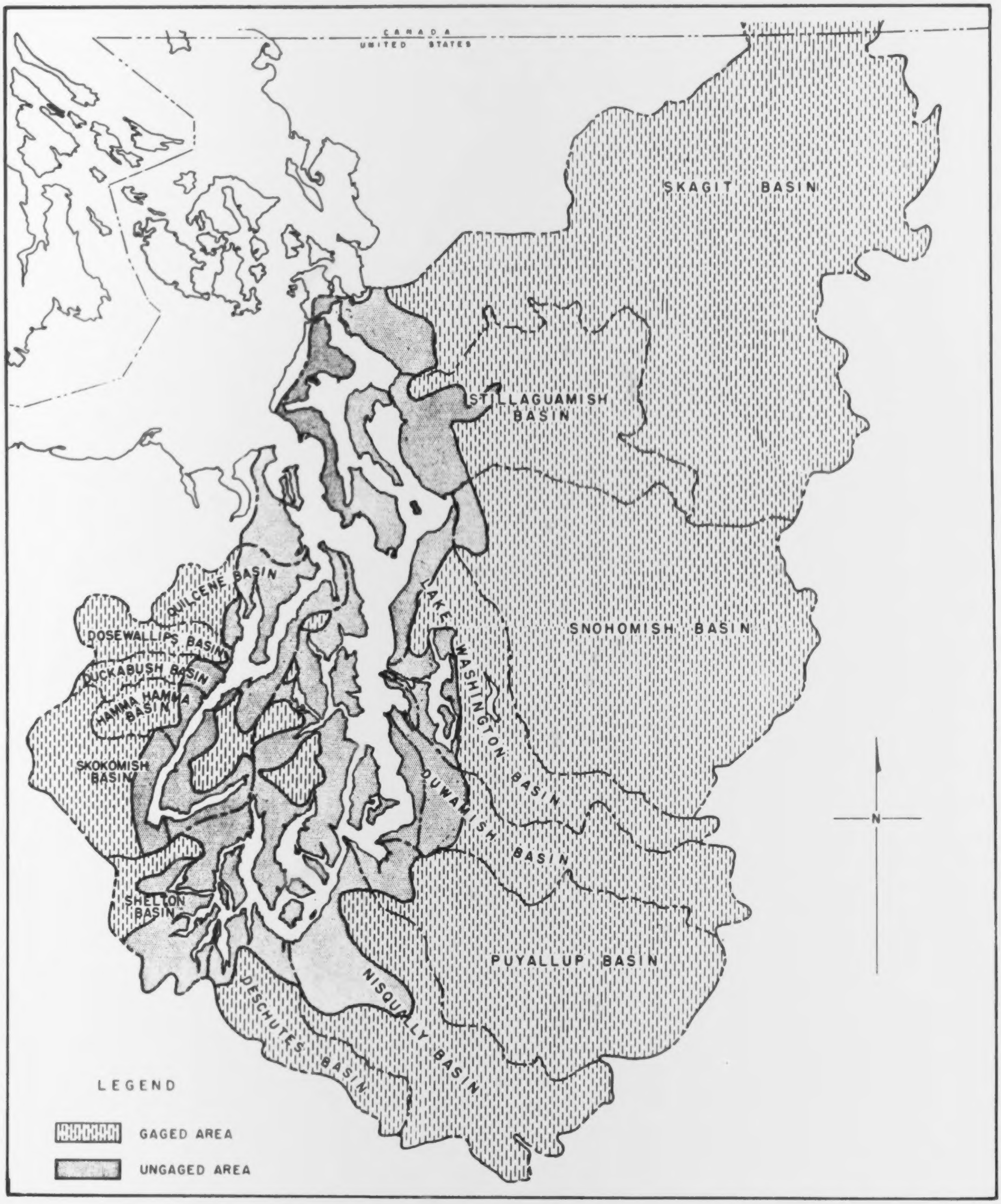
PUGET SOUND WATERSHEDS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DUWAMISH BASIN
PUYALLUP BASIN
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DESCHUTES BASIN
SHELTON BASIN
SKOKOMISH BASIN
HAMMA HAMMA BASIN
DUCKABUSH BASIN
DOSEWALLIPS BASIN
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N
LEGEND
GAGED AREA
UNGAGED AREA

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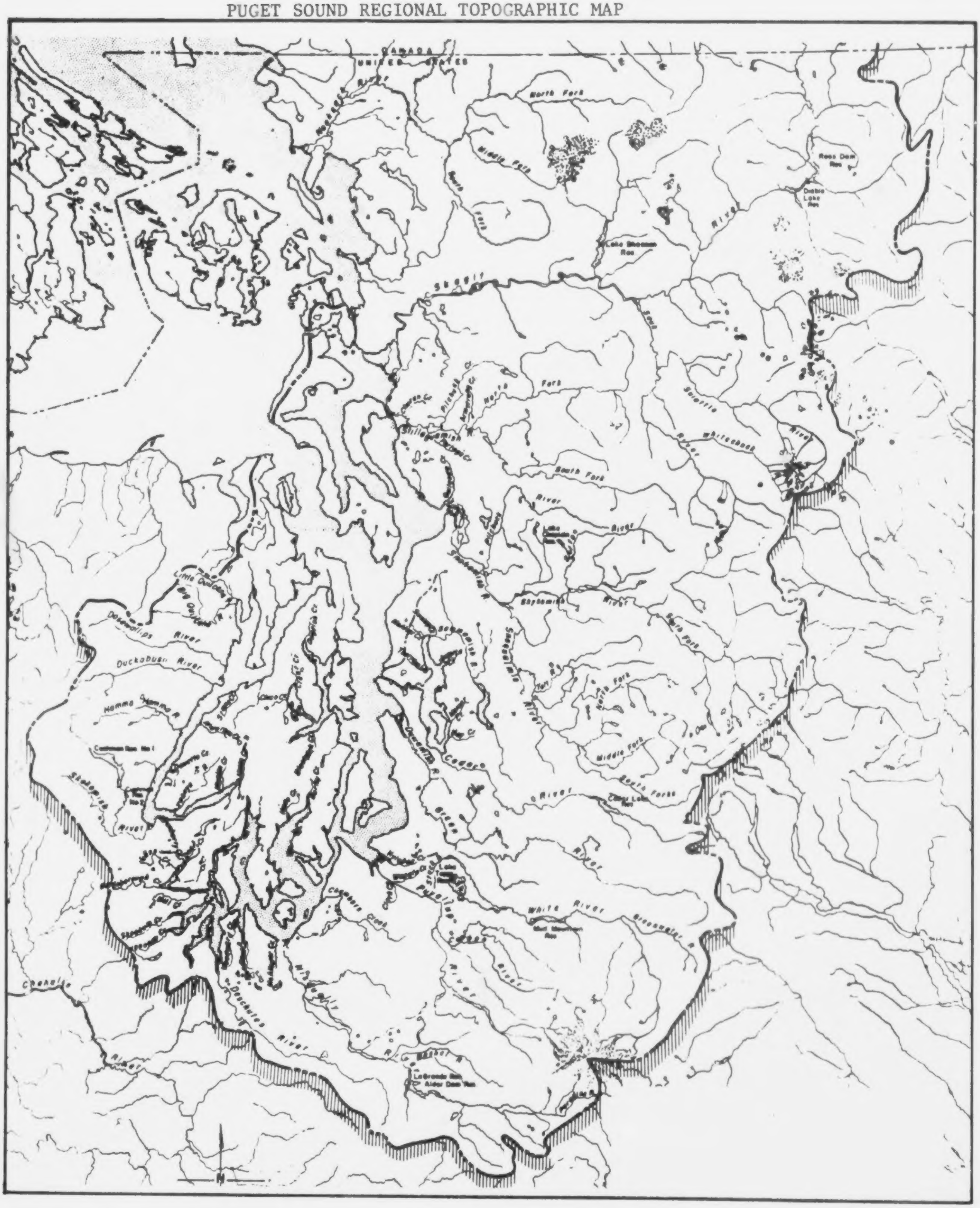
PUGET SOUND REGIONAL TOPOGRAPHIC MAP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UNITED STATES
North Fork
Middle Fork
South Fork
Ross Dam Res.
Diablo Lake Res.
Lake Shannon Res.
Skagit
River
Suiattle
Whitechuck
Stillaguamish
Pilchuck
South Fork
Skykomish
River
Snohomish
Snoqualmie
River
Tolt R.
North Fork
Middle Fork
Little Quilcene
Big Quilcene
Dosewallips River
Duckabush River
Hamma Hamma R.
Cushman Res. No. 1
Skokomish
River
Cedar
River
Green
River
White River
Mud Mountain Res.
Greenwater R.
Puyallup
Carbon
River
Nisqually
Deschutes River
Mashel R.
La Grande Res.
Alder Dam Res.
Chehalis
River
N

NAME ____________________

MARSHES, ESTUARIES AND WETLANDS *

"People in Washington Don't Tan, They Rust!" This quotation, popularized on t-shirts and bumper stickers, refers to a well know feature of the Northwest. RAIN! The rains of Washington are a necessary part of the ecosystem. They are an integral part of the water cycle.

Water is essential for life. A critical question might be, what would happen to all the plants and animals if it ever completely stopped raining? Drought! But an equally important question might be, from where does the rain come? The answer to this is the beginning of understanding the importance of the water cycle.

Rain falls to the ground, and because of gravity, begins to flow to the lowest point. Water drops flow together to form streams, then rivers. Always continuing to the low point, the water may collect in large basins, or depressions. Some water seeps into the ground, flowing in subterranean water systems called aquifers. Eventually, water may surface in springs, wells or as ground moisture. The waters continue to flow, eventually reaching the ocean.

The sun, heating the water, causes evaporation. The water molecules circulate in the atmosphere. As the air cools, the water molecules begin to reform as rain drops. The cycle begins again.

THE WATERSHED

The watershed is an ecological unit that can be defined by the geography of a basin. Simply put, the watershed is defined by the ridges or mountains that separate major river systems. Consider the watershed basin as a bowl. Water poured on the rim, either flows into the bowl or down the outside. The water flowing into the bowl, or basin, is identified as a single watershed.

Within the watershed are separate water course systems that have been identified and studied. Generally speaking, all the parts of the watershed have one thing in common, water. Additionally, these sections have soils that are water saturated. These are called hydric soils. Despite these similarities, each section has special properties that determine what kinds of plants and animals live there.

By focusing on the differences we can identify each component and habitat. Each water system can be examined for the role it plays in the total ecosystem and for its function within the watershed. Each can be valued for recreational, aesthetic or educational activities. Finally, adverse impacts created by humans can be studied.

Various organizations and agencies have classified, described and identified such 'wetlands' in Washington. To help you understand the watershed systems, the following narrative will introduce you to the terms used by the U.S. Fish and Wildlife Service in classifying the systems. Additionally, the descriptive names,

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*This reading is in part excerpted and adapted from the Coastal Zone Atlases of Washington Land Cover/Land Use Narratives by Albright, Hirschi, Vanbianchi and Vita. Published by Department of Ecology, June 1980. Permission granted by Fred Gardiner.

NAME ____________________

used by the Department of Ecology in constructing the Coastal Zone Atlases, will help define each system.

THE PALUSTRINE ENVIRONMENT

Palustrine is a word used to describe wetlands that are relatively small in size, with no active wave action, and no bedrock shoreline features. The water is generally not deep. Included in this watershed component are four habitat types that are structurally similar and provide similar animal habitat, but have different plant species. A similarity shared by all four is the presence of standing water or saturated substrate (ground).

The first of these four habitats is the Freshwater Marsh. The marsh is characterized by open standing water and herbaceous plants. The next two, Swamps and Bogs represent terminal stages of succession of wetlands, resulting in climax forests. Swamps are characterized by open water and the presence of trees. Bogs appear as filled in areas. The water lies beneath the vegetated surface. Ponds, the last of the palustrine habitats to be described, are typically shallow open water areas that are identifiably different than lakes. Generally, the edges of ponds are not definite and there is no wave action to speak of. Also, they are generally smaller than 20 acres in size.

Freshwater Marshes

Marshes are a major feature of freshwater wetlands in Washington. They occur throughout the state from just above sea level to high mountainous areas. All freshwater marshes form in blocked drainages and have standing water for all or part of the year. Marshes are dominated by herbaceous plants, distinguishing these wetlands from swamps in which shrubs and trees are dominant. Like other wetlands, they have often been filled, dredged or otherwise manipulated by human activities. They are also becoming increasingly recognized as valuable habitat for waterfowl, aquatic mammals, and amphibians and should be guarded with care.

Freshwater marshes perform an important function in the water cycle. Surface runoff accumulating in the marsh slowly seeps into the groundwater layer, replenishing subterranean reservoirs. The elimination of marshes in areas where groundwater supply is critical may decrease the charge rate of aquifers.

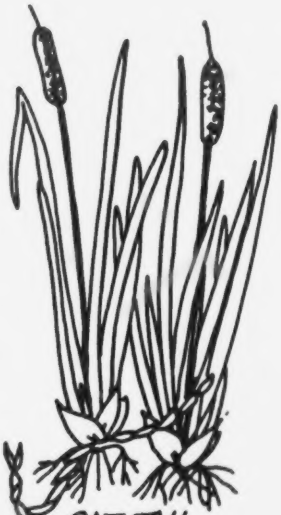
All wetland habitat types are natural flood control zones, able to accommodate large amounts of water without suffering damage. Marshes are no exception, and it has been estimated that a ten-acre wetland capable of accommodating several inches of water, will store over one million gallons.

Freshwater marshes are among the most susceptible of all wetlands to adverse impacts. They are easily drained or filled because they are often small and water levels are low. Wildlife use of the marsh and water level or quality can also be altered if surrounding vegetation is disturbed. In general, freshwater marshes and associated wildlife should not be encroached upon. Buffer strips of native vegetation should be maintained and will vary in width according to several factors such as:

1) Shape of drainage basin and topography.
2) Presence of sensitive species.
3) Presence of sensitive habitats.

NAME ____________________

Several plant species are characteristic of freshwater marshes in Washington, but perhaps none more so than common cattails. Many people equate marshes with cattails and rightfully so. They are a major feature of most freshwater marshes and have been put to many uses by humans, and support many familiar wildlife species.



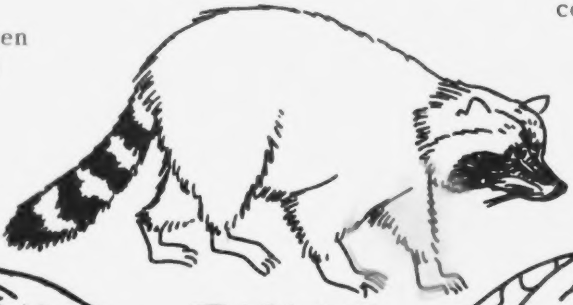
CATTAIL

Additional species include hardstem or softstem bulrush. Reed canarygrass, an introduced species, is very common throughout the Pacific Northwest, and often forms dense, solid stands in freshwater marshes. Other species include: creeping buttercups, yellow flag, California false hellebore, water and skunk cabbage.

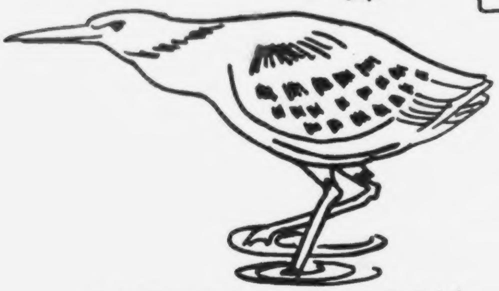
Wildlife

Representative animal species of the freshwater marsh include the following:

Birds	Mammals	Reptiles and Amphibians
great blue heron	Pacific water shrew	rough-skinned newt
American bittern	Townsend's vole	northwestern salamander
Canada goose	racoon	western toad
mallard	mink	Pacific treefrog
American coot	striped skunk	red-legged frog
belted kingfisher	river otter	bullfrog
barn swallow		common garter snake
long-billed marsh wren		
red-winged blackbird		
song sparrow		



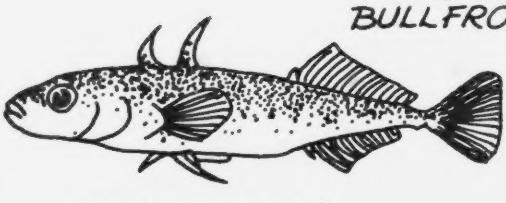
RACCOON



AMERICAN BITTERN

BULLFROG

Fish occur in marshes with permanent standing water but are very restricted in number of species; the three-spine stickle-back is often the sole representative.



STICKLEBACK

NAME ______________________

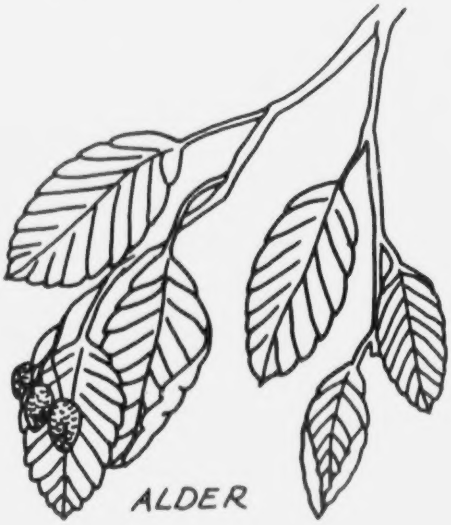
Freshwater Swamps

Like a bog environment, the freshwater swamp represents the final stage of aging of a lake or wetland. A swamp is characterized by the presence of woody plants distinguishing it from a marsh. It also has an open water area, distinguishing it from a bog.

Two major types of freshwater swamps occur, tree-dominated and shrub dominated, (and intermediate stages are not uncommon.) Shrub-dominated sites are generally wetter than those with well-developed tree cover.

Continuous woody cover is typical of most swamps, however, sites with uneven terrain frequently have open water.

Swamps with continuous tree cover are most common, and any one of several species may be dominant, or mixed stands may occur. Species include quaking aspen, red alder, black cottonwood, willows, western red cedar, and Sitka spruce. The understory is a dense stand of common cattail, black twinberry, skunk cabbage, water parsley, kneeling angelica, and occasionally crabapple, and yew. Scattered throughout the understory are raised spots with typical forest understory species, further diversifying this habitat.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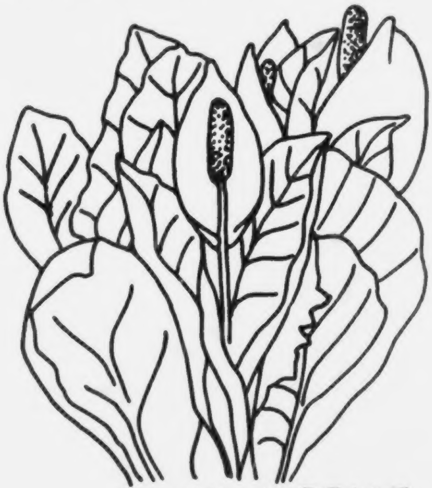
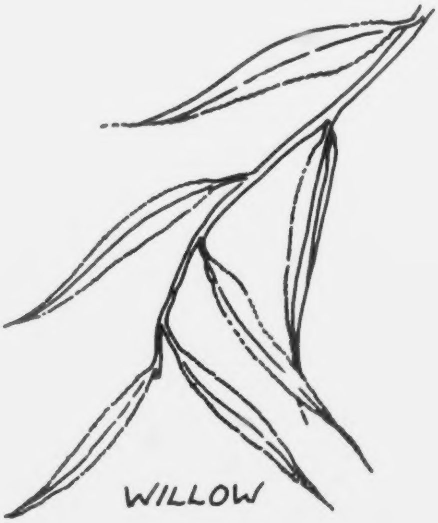
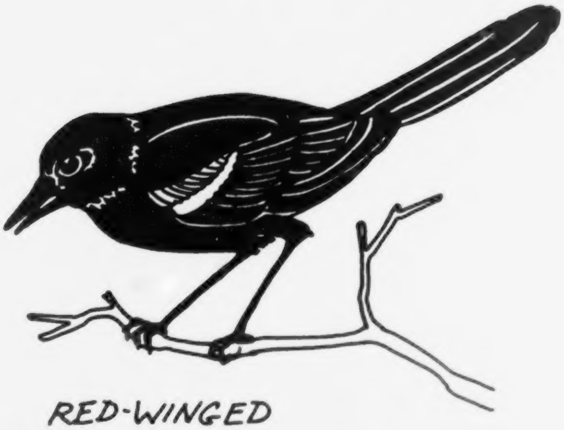

SKUNK CABBAGE


WILLOW

Swamp sandwort, currently included on the state working list of rare or endangered plant species, has been reported from coastal swamps in southwestern Washington and near Tacoma.

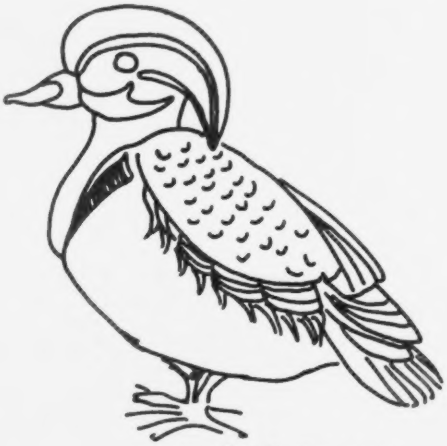
NAME ______________________

Many of the animal species associated with freshwater marshes also occur in swamps. Several ducks, blackbirds, herons, and amphibians are among the animals inhabiting both wetland habitats. Standing water and low, herbaceous vegetation within the swamp provides suitable habitat for these species while the presence of shrubs and trees increases structural diversity and the number of available niches. Woodland species often forage or nest in swamps, and typical marsh inhabitants which nest in trees benefit from their interpersion within the marshy understory. Snags are often present and are especially beneficial for cavity nesters.



RED-WINGED BLACK BIRD

In general, the diversity and abundance of animals within a swamp are greatest where trees are scattered within a matrix of open water and marsh. Characteristic species include some of our more intriguing wildlife such as the wood duck. These ducks were once near extinction due to overhunting and habitat destruction. The brightly colored male with his splashes of green, blue, red, and purple is one of our most beautiful birds. Wood ducks nest in natural cavities in trees, 5-40 feet above the water. The abandoned nest of a pileated woodpecker is often used as a nest site and they will also use suitable nest boxes. Ground dwellers also include many terrestrial species, and bear, deer, and elk are common



WOOD DUCK

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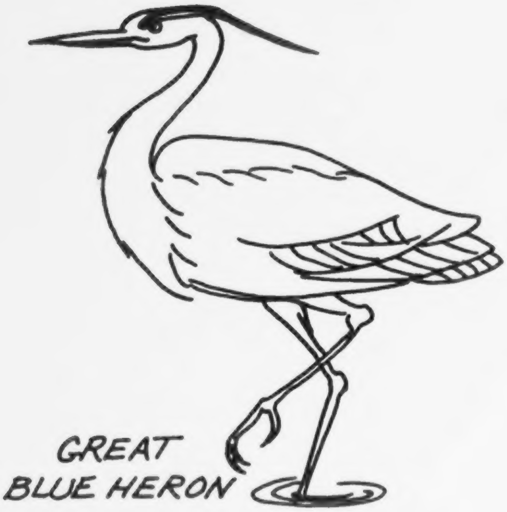
inhabitants. Densely forested swamps may also support a significant percentage of nesting populations of great blue herons in the Coastal Zone. For example, one of the largest known rookeries in the state, on Samish Island in Skagit County, is within a black cottonwood swamp. Other birds found are violet-green swallows, tree swallows, chickadees, common flickers, and downy woodpeckers.



Bogs

Bog development begins with the establishment of sphagnum, and other typical bog species around the edge of a lake, or in a marsh or swamp. As the mat of bog vegetation spreads out into open water or around exisiting vegetation, chemical and physical conditions become more favorable for the development of a bog, i.e., drainage is retarded by the mat, and the water and substrate becomes more acid from the expanding growth of sphagnum.

Bogs are fascinating natural communities, displaying a combination of physical, chemical, and biological features unduplicated in any other habitat type. They are relatively common throughout the glaciated portion of the Puget Trough. Bogs are characterized by poor drainage, highly acidic water and substrate, low nutrient levels, and a well-defined plant community. The terms "bog," swamp," and "marsh" are often used indiscriminately, but the habitats they describe are very different. The characteristics of these three types are compared in the following table (next page).

When bog vegetation is invading open water, the leading edge or pioneer zone, usually contains woody shoots of Labrador tea and bog laurel, as well as buckbean and purple cinquefoil. These woody stems help support the advancing sphagnum mat, the leading edge of which initiates the herb zone. Typical species in this zone include cotton grass, beak rush, several sedges, sundew, bog St. John's wort, and bog cranberry growing in a solid sphagnum mat. The next zone, the shrub-tree zone, generally has a fewer number of plant species than the pioneer and herb zones, but greater structural diversity. Shrubs include bog laurel, labrador tea, and sweet gale, often forming dense stands. Trees most tolerant of the bog environment are western hemlock, lodgepole pine, and western white pine, although western red cedar, Sitka spruce, and cascara may be present. The effects of the bog environment on tree growth are illustrated by a study in Western Washington reporting 30-70 year old western hemlocks standing only 5-6 feet tall.

A COMPARISON OF BOG, MARSH AND SWAMP CHARACTERISTICS
(After Fitzgerald, 1977)

		BOG	MARSH	SWAMP
Drainage		blocked - allows accumulation of organic material; further congested by bog development	does not allow accumulation of organic material	
Depth		deep or shallow	shallow	
Filling-in		floating mat invades open water-fills in from top and bottom	open water invaded by submergent, emergent, or floating vegetation--fills in from the bottom upwards	
Water Quality		brown, low nutrients, strongly acidic, low oxygen level	green, high nutrients, acid or alkaline, high oxygen level	
Bottom		false bottom often formed by the accumulation of colloids	No false bottom	
Micro-organisms		Few	Abundant	
Vegetation:	mosses	abundant, especially *Sphagnum* sp.	relatively scarce	
	herbs	sundew, orchids, bog St. John's wort, sedges,	sedges, rushes, grasses	sedges, rushes, skunk cabbage
	shrubs	bog laurel, Labrador tea, bog cranberry	absent	red-osier dogwood, salmonberry, hardhack
	trees	lodgepole pine, western hemlock, white pine	absent	quaking aspen, willows, red alder, Sitka spruce, western red cedar
Fauna		black bear, deer, meadow mice, ground and shrub foraging birds, habitat of Beller's Ground Beetle (proposed R & E species), frogs, salamanders	waterfowl, mink, blackbirds, bittern, rails frogs, salamanders	Wood Duck, woodpeckers, swallows, River otter, often includes many marsh spp. also

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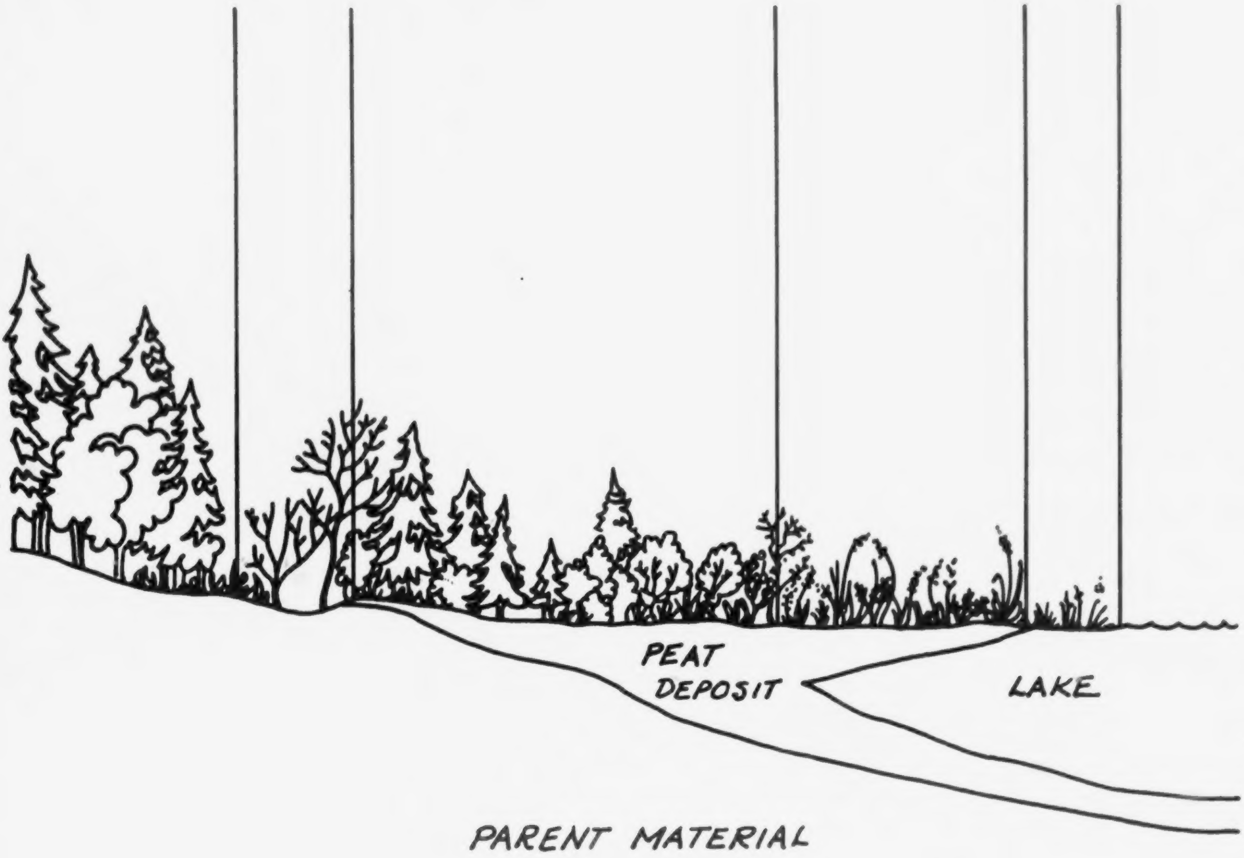
The herb zone and the shrub-tree zone usually occupy the largest area of a bog, and are the most conspicuous zones. Between the bog and the adjacent upland, there often occurs a marginal ditch, especially at very mature sites. Conditions in the marginal ditch are similar to those found in swamps, i.e., well oxygenated, nutrient-rich water. The vegetation reflects these conditions, and typical swamp flora often develops.



One of the most characteristic bog vertebrates is the Townsend's vole. These voles, also know as meadow mice, are frequently encountered in coastal bogs. Their presence is noted by a maze of open runways and tunnels lacing through the sphagnum mosses. They feed on a variety of herbaceous plants and may in turn become prey of coyotes, red-tailed hawks, or marsh hawks. Other herbivores which frequent bogs include various hares and deer. If sufficient open water is present, beaver, river otters, and waterfowl may frequent the bog and some nesting is likely to occur in this pioneer zone. The upland edge of bogs is used by a wide variety of wildlife, as with other wetlands. Birds of prey including owls and hawks will use the large trees surrounding the bog and fly over the open sphagnum mat where voles provide an abundance of prey.

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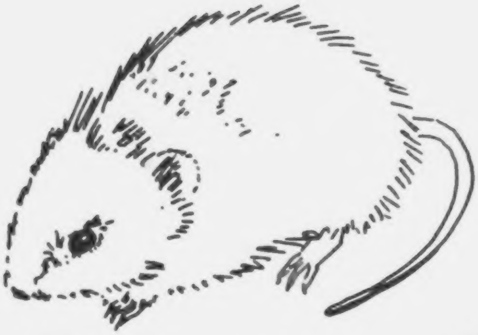
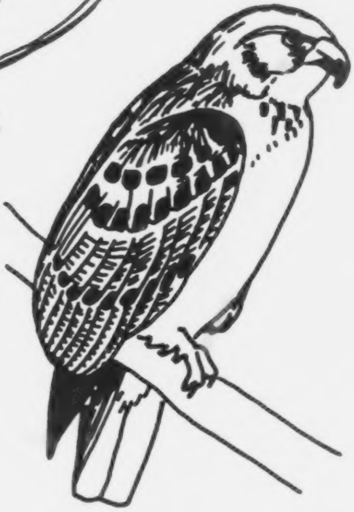
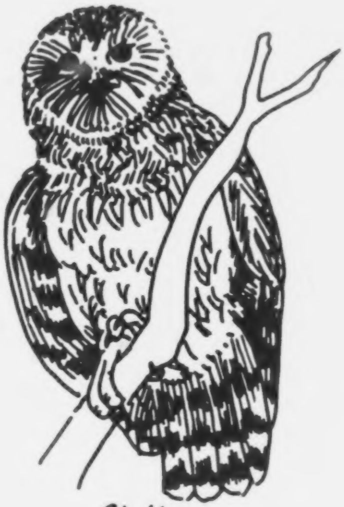


TOWNSEND'S VOLE



RED-TAILED HAWK



OWL

The plant and animal communities of both swamps and bogs are dependent on a relatively stable water level. The most widespread disturbance to these habitats has been the alteration of the water level, often by filling or draining. The impact of this type of disturbance is to hasten succession by artificially creating drier conditions, and the destruction of habitat for animals dependent on these wetlands. Swamps are particularly susceptible to blocked drainage and a resultant rise in water level. Such disturbance may push succession back to the pond stage by raising the water to an intolerable level, resulting in the death of swamp vegetaion. If propagules of bog vegetation are available, blocked drainage may also set the stage for the development of a bog.

In past years, peat removal has been a major disturbance in Washington's sphagnum bogs. Sphagnum peat has been used for packing vegetables and live plants for shipment, building insulation, as a soil amendment, for surgical dressings during World War I, and as chicken litter. The impact of commercial peat removal is devastating to the biological community of a bog.

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A most frequent disturbance observed during this study was filling for residential constructions, and encroachment by residential and commercial development. The inherent problem with building on unstable substrate is discussed in Peat Resources of Washington, by George Rigg:

> "A few small sphagnum bogs in Seattle passed directly from their natural condition to sites for small homes. The construction of houses was begun without adequate investigation of the material on which they were to rest, and difficulties were encountered. Some concrete foundations sank into the bog before the houses were finished. Some occupied houses sank irregularly two feet or more. Some concrete sidwalks sank a few feet, and some of them on the margin moved sideways as much as four feet. One bulldozer plunged into the soft peat and was recovered only with difficulty."

Ponds

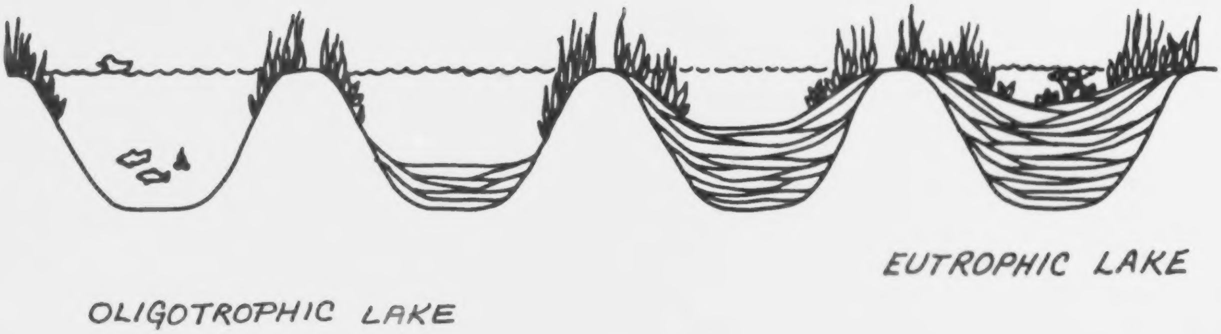
Ponds are typically shallow and lack extensive open water areas. Thus, their primary producing zone is nearshore water (i.e., the littoral zone). Bodies of water mapped as inland ponds and coastal ponds cover less than 20 acres. Inland ponds are situated at high elevations. Coastal ponds are located along the beach fringes behind drift logs and at the base of shoreline bluffs, or form on river deltas when old stream channels are blocked by levees or natural stream course drifts.

Ponds, like lakes have a considerable amount of open water. Consequently, the plants and animals of this habitat are similar to those of the lacustrine environment.

LACUSTRINE SYSTEM

The lacustrine system can be simply defined as a lake system. Lakes are similar to ponds but are larger, generally over 20 acres in size. They show evidence of wave action, and have exposed mineral earth at the shoreline. Lakes, unlike ponds, lack significant amounts of trees, shrubs or emergent plants. Open water areas are relatively large compared to nearshore zones and are the primary producing regions of the lakes. Lakes are important in the Pacific Northwest as wildlife habitat, recreation, and as part of watersheds.

Lakes can change over time. The succession of lake form proceeds as nutrients are added to the lake through runoff and leaching from the soils and rocks of the surrounding drainage basin. Man-made effluents which enter water bodies increase the rate of eutrophication (progressive nutrient buildup). This results in an increase of concentrations of nutrients essential to plant productivity, primarily that of algae. The process of eutrophication in the lake is accompanied by increases in species diversity of phytoplankton and increases in total algal biomass. Then as eutrophication proceeds, diversity decreases and the flora becomes dominated by green and blue-green algae. The lake may eventually age to a shallow, warm, turbid, highly productive lake with water of decreased quality and limited usability to humans and cold water fish. Succession will continue with the establishment of a terrestrial community.

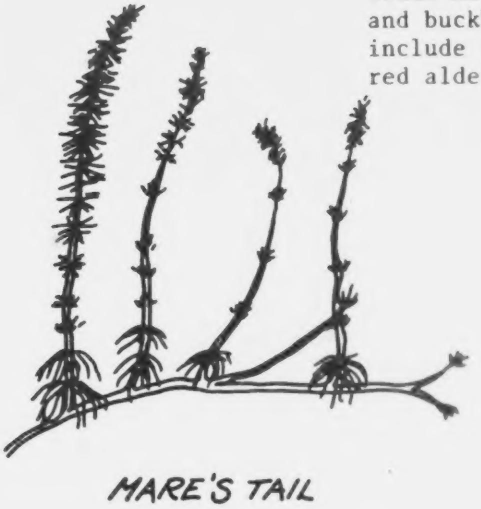


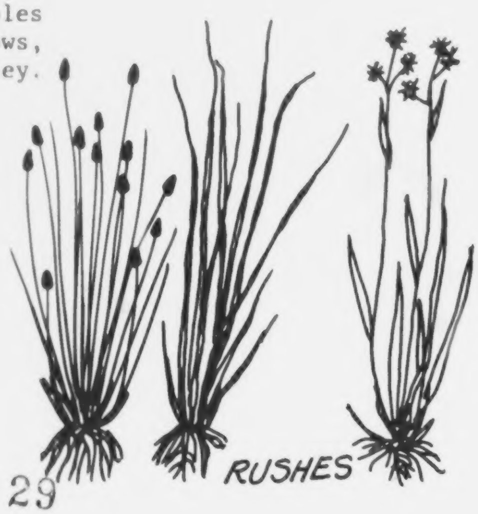
Lakes and ponds are important to wildlife all year long. In spring, lakes are used for breeding and rearing young and are rich sources of high protein foods needed for the energy demands those activities require. In winter, lakes are used as feeding and sheltered resting areas by wildlife.

Lakes and ponds are used by many species. Adjoining terrestrial habitat provides cover and nest sites while aquatic areas provide food. Lakes and ponds and associated wetlands act as corridors as part of migration routes for waterfowl, shorebirds, songbirds, and fish. Many stream animals enter lakes, but their distribution remains near the stream mouth and along the lake shore. Other river and stream fish, such as sockeye salmon and longfin smelt, spawn in rivers and streams and migrate while young to lakes for growth to the adult stage.

In the nearshore zone, plants belonging to two major groups are responsible for primary production. Algae, which may be micro or macroscopic, attached or free-swimming, and vascular plants, which are often dispersed according to growth habit. Vascular plants may be:

1) Emergent - rooted in the bottom sediment but with stems, leaves, flowers, and fruits above the water surface. Emergent species include mare's tail, arrowhead, and buckbean. Other examples include common rush, willows, red alder, and water parsley.





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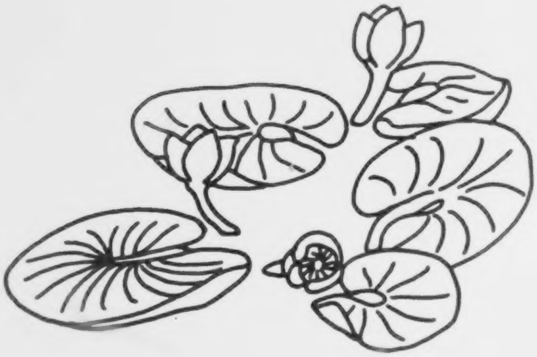
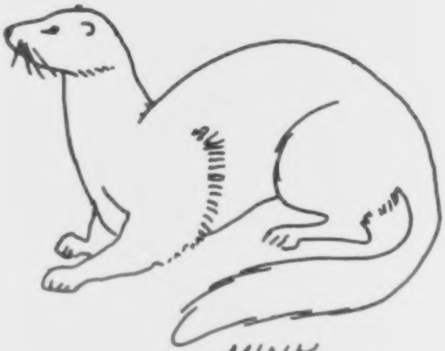
2) **Floating** - rooted in the bottom sediment with leaves floating at the surface, and flowers and fruits often just above the surface. Examples of rooted floating species include spatterdock, fragrant water-lily, water shield, pondweeds, and water-starworts.

Free-floating species include one of the smallest flowering plants of the coastal flora (water lentil), the smallest fern (water fern) and two species of liverwort.

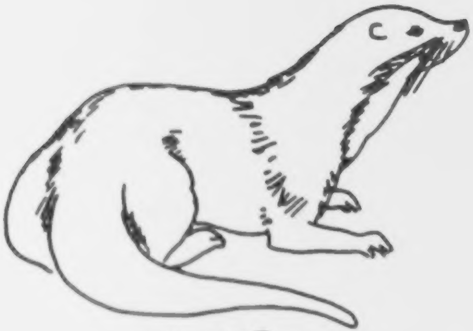


WATER LILY

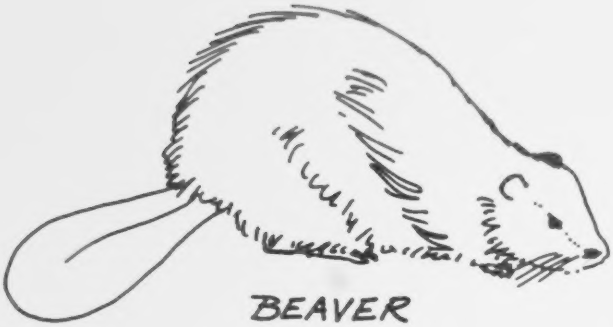
3) **Submergent** - plants that grow beneath the surface of the water and may be rooted or free-floating. Important plant species in this group are coontail, waterweed, wavy water-nymph, and common and humped bladderwort, and horned pondweed.



MINK



OTTER



BEAVER

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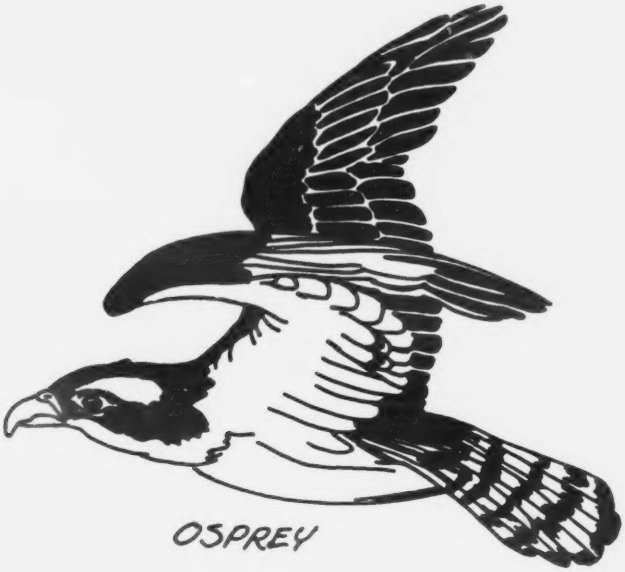
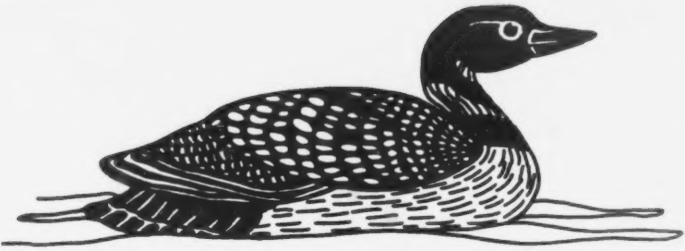
Many furbearers such as raccoon, river otter, beaver and mink, rely heavily on these breeding habitats for food, protection, breeding, and rearing areas for their young. Deer and elk use the emergent vegetation and the shoreline trees and shrubs for food and cover. Animals also use quiet pools to escape insects during the summer. Frogs, salamanders, newts, snakes, and turtles rely on lakes and ponds for reproduction, feeding, and cover. Numerous freshwater fish species are also dependent upon the existence of lakes and ponds, such as sticklebacks, sculpins and trout.



OSPREY



COMMON LOON

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There are some birds which generally prefer lakes over ponds, such as the common loon, lesser scaup, osprey, and swans. These and other species are often present or often more abundant on lakes because of the larger surface area and greater food abundance. Some species may also be more abundant in coastal lakes and ponds because of their proximity to marine waters -- bald eagles. Also found are mallards, scaups and American bitterns. Each lake and pond inhabitant is interrelated, and together they comprise a community typical of others while unique to that location.

In recent years, we have become more aware of the value of lakes and ponds and have come to understand more about the impacts some activities of people have on ecological systems. Efforts have been made to maintain and/or improve water quality and preserve habitat. Continued efforts should be made to safe-guard these valuable wetlands from destruction if we are to continue to appreciate them as wild ecosystems.

Human activities have the greatest impacts on lakes and ponds. Use of herbicides, insecticides, and fertilizers, road building, construction and recreation affect lake and pond communities.

THE RIVERINE SYSTEM

The riverine system includes all wetlands and deep water habitats contained within a channel. The channel typically links two bodies of standing water and the water is continuously flowing. In essence, the riverine system is the definition of rivers and streams.

Rivers are an integral part of the earth's water cycle. They are the primary link between terrestrial and standing water habitats. Nutrients collected from runoff and groundwater are distributed within rivers and transported to other habitats. Rivers carry enriching nutrients to lakes and estuaries, making the latter a highly productive area for fish, oysters, waterfowl, and several other organisms. Rivers also function as spawning and rearing areas for fish and are a source of food for riparian wildlife.

Rivers and streams in western Washington are relatively short. There are considerable channel variations due to differences in topography of each drainage basin or valley. The river channel is fashioned and maintained by water flowing in it. Major sources of water flowing in a stream channel are surface runoff and groundwater discharge. Gravity and friction direct the water's action upon a given area; topography and geology determine the type of riverscape formed. If the valley is partially blocked by glacial debris, the river may silt and level the valley floor, forming a lake or meandering channels. A narrow valley with steep slope forms a fixed channel perhaps down to bedrock.

Currents, substrate, and water depth dictate what life forms occupy an area of a stream. Riffles are characterized by shallow water and a fast current, which keeps the bottom relatively clear of silt and provides a firm substrate. Riffles usually provide a great variety of niches for aquatic invertebrates, upon which many aquatic animals feed. Characteristic invertebrates in this area firmly attach or cling to the firm substrate. However, fishes, such as salmon and trout, must resist the downstream current and are accordingly strong swimmers.

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Pool areas are deeper than riffles and the current is reduced. Silt and other loose materials settle to the bottom creating a softer substrate. Silty bottoms of pools are unsuitable habitats due to scouring by flood waters; however, the silt substrates are favorable for burrowing animals. Stream fish take refuge in these pools and feed in or at the base of rapids.

Stream bottom type is very important in determining the nature of communities and the population density of community dominants. A river or stream may have many different substrates throughout its length and the stream biota will vary accordingly. Habitats created by rivers are highly dynamic. Stream animals have narrow tolerances to many environmental factors. Certain limiting factors determine the life capable of existing in the streams. Stream life is especially sensitive to reduced levels of oxygen and any type of organic pollution that reduces the dissolved oxygen supply. Stream temperature is also a limiting factor to stream biota. Turbidity and light intensity are important limiting factors to stream life. These factors limit primary producers such as algae and moss. Turbidity can also interfere with fish ability to locate prey.

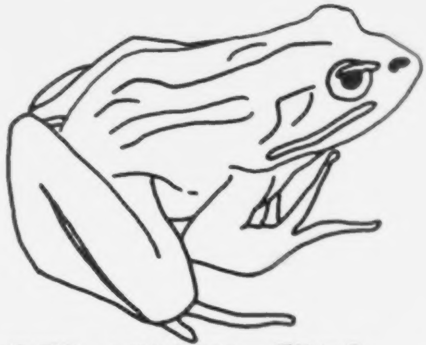
All stream-inhabiting salmon and trout have the following general optimum requirements:

access
streamflow (without flooding or drought)
substrate (clear)
cover
temperature
oxygen
clarity

The streams of the Pacific Northwest are among the richest producers of fish in the world. These highly productive streams derive most of their energy for productivity from outside the river system.

It has been estimated that a small stream imports over 90 percent of its energy input from terrestrial surroundings. Detritus enters the stream in the coarse form of leaves, needles, twigs, branches, nuts, flowers, and as soluble organic matter leached from these materials. As little as 1 percent of the stream system energy is derived from stream photosynthesis by mosses and phytoplankton. Primary producers of energy in streams are fixed filamentous green algae, encrusted diatoms, aquatic mosses and some vascular plants.

GARTER SNAKE



RED-LEGGED FROG

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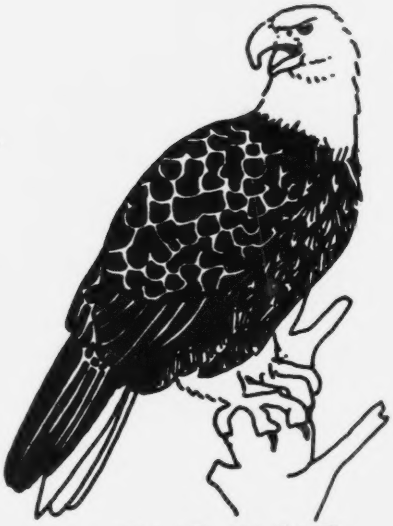
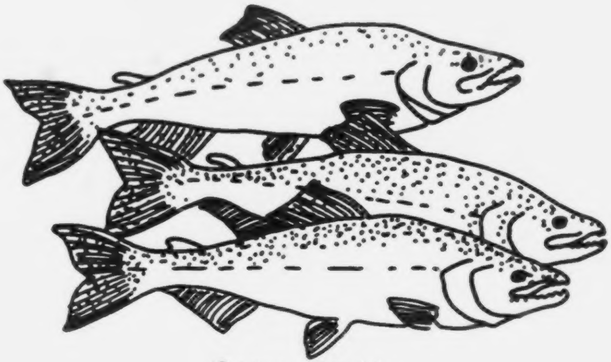
Rivers and streams are one of the more important wetland habitat types used by wildlife. River habitat is used for spawning grounds, nursery and rearing areas, resting areas, cover and as a food reservoir for aquatic animals. Terrestrial animals also use rivers and associated habitats for food, cover, nesting, travel routes, and play areas.



BALD EAGLE

Rivers and streams are primary habitat to the following species: great blue heron, harlequin duck bald eagle, osprey, spotted sandpiper, belted kingfisher, dipper, and beaver.

Chinook, coho, chum, sockeye, and pink slamon, steelhead and cutthroat trout and dolly varden are all very valuable commercial and/or sports fishes. These fish and others depend on rivers and streams for their continued existence. Several other fish, particularly sculpins, are an abundant and valuable source of prey for other fish, birds, and mammals. Many other species use rivers and streams and their associated riparian habitat. These edge areas provide rich feeding grounds, corridors and cover for river otter, raccoon, mink, muskrat, eagles, herons, and kingfishers.



CHINOOK

Other riverine organisms include: Olympic salamander, Northwestern salamander, red-legged frog, Pacific tree frog, common garter snake.

Rivers benefit industries and recreationists and also contribute to the function of the global ecosystem. Rivers and associated ecosystems provide rich habitats for wildlife and should be managed with this in mind. Changes in a watershed can affect a river and its biota, as well as the biota of many interdependent habitats.

The value of a pristine stream to an angler whiling away a pleasant afternoon, or the heart-shaking excitement of a rafter negotiating rapids, or the joy of a child when he first skips a stone over a calm pool must all be measured before river management decisions are made.

ESTUARINE ENVIRONMENT

Estuaries are semi-enclosed basins with an opening to the ocean, which is diluted with fresh water from rivers or precipitation. Estuaries are one of the most highly productive and complex ecosystems in the Pacific Northwest. These

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moderately protected embayments are strongly influenced by marine waters from the open sea and by fresh water drainage. Flora and fauna are adapted to marine conditions and benefit from protected waters within the shelter of the bay.

Salinities, flora, and fauna vary greatly in estuarine zones of fresh and salt water mixing. This zone of variable salinities creates stressful conditions for species adapted to strictly fresh or strictly marine environments. However, this mixing zone also produces conditions in which tremendous quantities of sediments, nutrients, and organic matter are exchanged between terrestrial, freshwater, and marine communities. Many organisms benefit from this effect and are dependent on these rich estuarine ecosystems which are composed of many interrelated parts.

Estuaries are highly dynamic environments due to the action of river flow and tides. At the mouths of rivers there is often a two-layer water system. At low tide with a high river flow, the surface water is fresh, while the bottom water is quite salty. Estuaries have such high production levels because they serve as nutrient traps. Stratification of salt and fresh water can hold nutrients in the estuary where they remain until used by estuarine organisms. It is important to note that pollutants get trapped in the same manner in which nutrients are retained and recycled in the estuarine sytem. Pollutants are then transferred through food webs based on estuarine productions. Toxins are often concentrated at higher trophic levels at which human consumption occurs.

The physical properties of estuaries vary depending on the volume and contents of river water released, structural components of the estuary bed, tides, and microclimate. They are extremely stressful environments for many aquatic animals and plants due to daily and seasonal changes in salinity, dissolved oxygen concentrations and tidal action.

Estuarine organisms have developed several ways to reduce the effect of changing salinities. Some animals escaped higher salinities by moving across salinity gradients within the estuary (by moving father up or downstream). Many estuarine animals cope with their environment by reducing contact with adverse salinities. Annelids, molluscs, and fish produce slime or mucus to protect themselves. Polychaetes and crabs plug up their burrows durings period of high or low salt conditions. Hydroids, annelids, and molluscs contract their muscles to reduce their surface volume and clams and barnacles close their shells. Other animals go into highly resistant resting stages during severe conditions, and bacteria form spores or cysts.

All estuarineanimals have some ability to regulate the amount of salt in their body fluids. Flounders can control the amount of salt coming into their bodies better than many other fish. The most efficient regulators are migrant species moving from and to sea water and fresh water. Migrating salmon undergo dramatic exchanges in salt concentrations in their blood and the amount of urine flow as they go from salt to fresh water.

Estuaries are composed of many intergrading habitat types, including open water, mudflat, marsh, sand, and fresh, marine and brackish waters. Each habitat type supports a characteristic community of plants and animals. Each should be examined separately.

Typical estuarine birds are often divided by foraging strategies of individual species. Cormorants and waterfowl, canvasbacks, grebes, scoters, and mergansers, use open water areas for resting and feeding. Near by salt marshes offer waterfowl and shorebirds cover for breeding, resting, and feeding. Least Sandpipers

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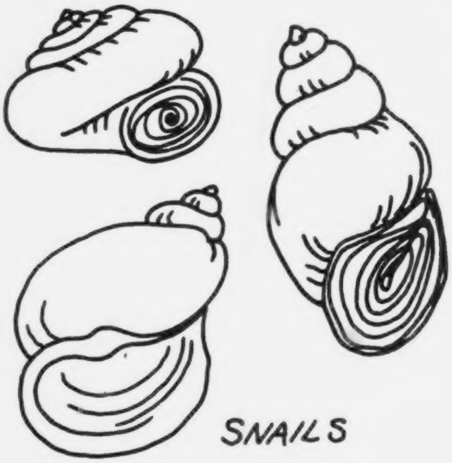
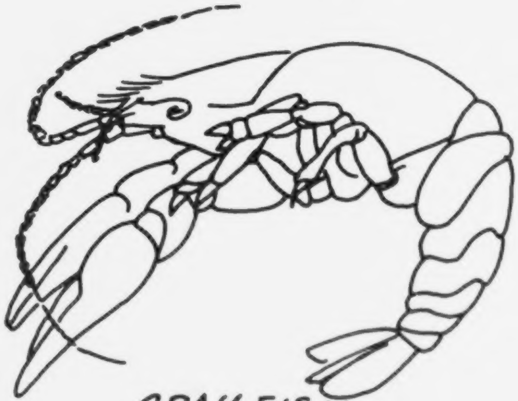
have very short bills and feed back from the water's edge. Greater yellowlegs, having longer bills and legs, feed up to their bellies in water and may immerse their whole heads while foraging. Small sandpipers, in general, are more restricted to intertidal flats although many also use salt marshes.

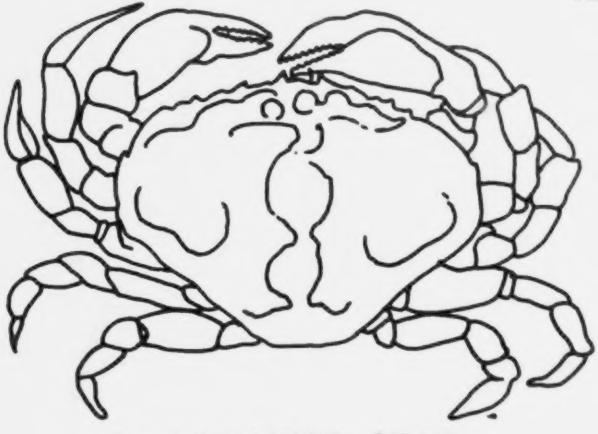
Mammals, such as raccoons, skunk, deer, elk, and river otters, use salt marsh areas and tidal flats. Harbor seals and Pacific Harbor porpoise feed in the open waters of estuaries. Local fish and aquatic invertebrate species composition changes with seasonal variations in salinity. Estuarine fish and invertebrates can be divided into three major groups, those occuring in fresh, brackish and salt intrusion waters.

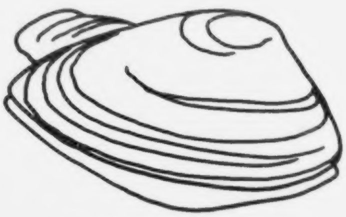
Fresh waters: snails, clams,polychaetes, oligochaetes crayfish, isopods, amphipods, and immature insects, especially chironomid larvae and newly hatched sand shrimp.


SNAILS


CRAYFISH

Brackish water: (mixed salt and fresh) isopods, immature sand shrimp, amphipods, copepods, and hydroits. Adult and immature sand shrimp, Dungeness crab, amphipods, isopods, and clams occur in waters nearer the ocean.


DUNGENESS CRAB


BUTTER CLAM

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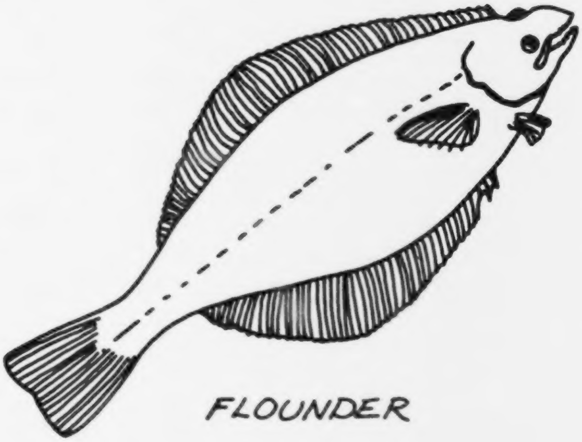
Salt Intrusion waters: starry flounder, prickly sculpin (a freshwater fish), Pacific staghorn sculpin, longfin smelt, Pacific tomcod, Pacific snakeblenny, anchovies, steelhead, cutthroat tout, and chum, king, chinook, sockeye, and pink salmon.

Plankton feeders which eat large quantities of copepods include:
snake blennies, longfin smelt, and juvenile starry flounder.

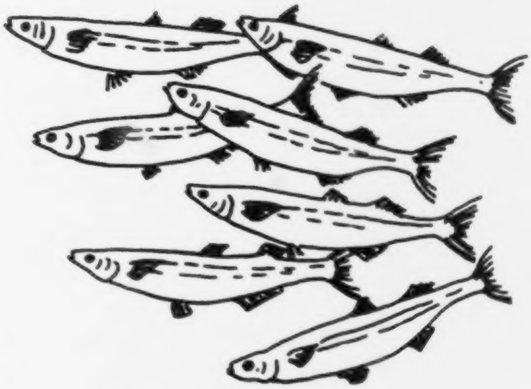
Bottom feeders, fish eating amphipods and and polychaetes include:
larger juvenile starry flounder, prickly sculpin, and sturgeon.

Consumers of fish include:
Pacific staghorn sculpin and sand sole.

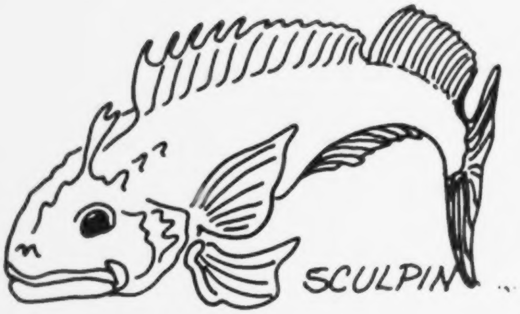
Fish with wide range of food habits include:
staghorn sculpin, young lemon sole, and tomcod.



FLOUNDER



SMELT



SCULPIN

Estuaries are nursery grounds for many species and serve as corridors for species entering and leaving fresh and salt water. Juvenile salmon use estuaries as feeding areas before entering the sea and the adults use estuaries before entering fresh water to spawn. Starry flounder also use fresh water areas in the upper estuarine river zone as juveniles and move through the estuary toward marine waters as adults.

All estuaries of Washington have been modified to some degree by human activities; some have been severely altered. Estuaries provided most of the level ground along the coast and were logical locations for early development in Western Washington. The proximity to the sea, rich fishing grounds, potential farmland, and the protection they afforded from harsh oceanic conditions provided incentives to establish coastal cities, trade, and cargo centers. River mouths and adjacent marine waters also provided a convenient though ill-advised means of disposing urban and industrial wastes.

NAME ____________________

Many people use estuaries for recreation. Sailing and other water activities can be done in open water areas of the estuary. Estuarine areas provide incredibly rich habitat for wildlife and wildlife watchers can observe a great diversity of species. Open and nearshore waters, tideflats, eelgrass beds, and marshes support large numbers of aesthetically valuable wildlife.

Specific Impacts on Estuarine Environments

1. Reduced River Flow.

   Reduced river flow from drought or the building of dams and reservoirs can have extreme long-term effects on estuarine species composition. Increased salinities force fresh water species farther upstream and out of the estuary.

   The current system can be so altered with decreased river flow that shoaling and scouring can set up completely different physical conditions. The estuarine substrate is an important habitat to many invertebrates and severe changes in it can be detrimental to them.

   Decreased river flow from dammed rivers or occasional drought results in a decrease of dissolved nutrients into estuaries. Rivers are a major source of organic materials that are used by estuarine organisms.

2. Development and Pollution.

   One of the reasons industry uses estuaries is water availability for transportation, processing, and waste disposal. Unfortunately, many of these uses degrade the estuarine environment by increasing sedimentation, turbidity, and nutrients that lead to eutrophication, lowering dissolved oxygen levels, and introducing pollutants into the food web. Marshes and tidal flats, which produce vast amounts of food, have been destroyed with development. Estuaries are vulnerable to pollution because of their nutrient trap mechanism.

3. Red Tides

   Toxic red tides are caused by high population levels of the red pigmented dinoflagellate (Gonyaulax catenella). These dinoflagellates produce one of the strongest neurotoxins known which can cause mass mortality of fish, shellfish, and humans that eat the poisoned animals. Gonyaulax catenalla populations bloom regularly during warm months along the outer coast and irregularly in north and central Puget Sound. Red tides are reportedly increasing on a world-wide basis. This may be due to agricultural activities which increase amounts of runoff and nutrients entering marine water which then trigger dinoflagellate production.

Estuaries are valuable and delicate ecosystems. Washington depends on estuaries for its fisheries, industry, recreation, and support of its wildlife. If we are to continue to benefit from one of the richest environments in the world, we must protect these systems from pollution and destruction.

Slide Show

WETLANDS: A WATERSHED PERSPECTIVE

1. Into these Pacific Northwest hills and mountains, the autumn and winter rains fall. As more rain falls, the drops come together to form little streams, which tumble down the mountainsides.

2. These streams pass into basins, or depressions, many of which were formed by the early glaciers. These basins hold back the flood waters until eventually the basin fills and breaches the edge. Then once more the water flows downhill.

3. As each stream continues, it is joined by other streams. Some of these other streams are formed as the mountain snows melt under the warmth of the spring and summer sun. As the streams flow into the lowland area, the swollen waterways, now called rivers, continue their course to the sea.

4. Often river waters are diverted on their way to the sea, pausing in large low land depressions, forming lakes and ponds. Other lakes and ponds may be formed when the rains come and the water flows into the low level basins. Dams also still the flowing waters into lakes upstream of the dam.

5. Eventually, the water which began as rain drops in the mountains winds its way to the sea. The river reaches the sea, flowing through delta lands formed by the slow moving stream and the deposited upland sediments.

6. The surface waters are the most visible part of the watershed. Below ground, aquifers filter, cleanse and retain water as part of the water table. These ground waters may eventually resurface as springs or ground seepage to become part of the visible watershed.

7. Both the surface and subterranean waters are important parts of the total hydrological cycle. The water which began as rain or snow followed a watercourse through ponds and lakes and streams and rivers, eventually reaching the sea. Some of the water was used by plants and animals and returned to the atmosphere through respiration or transpiration.

8. Part of the water reaching the sea will be evaporated by the sun. The clouds thus formed will return the moisture to the land through rain or snow. The water cycle will begin again. At this point let us examine more closely the watercourse we have just described.

9. As rain or snow falls, the water becomes part of the watershed. The watershed is defined geographically by encircling ridges, mountains or hills which separate one large basin from another. Within a basin, the rainwaters tend to flow together, toward a common watercourse. The watershed is also an ecological unit. The water system and the adjacent vegetation interrelate as an inseparable unit. Within the system, specific and identifiable wetland habitats function to recycle water within the total ecosystem. Let us examine those habitats.

10. The first major freshwater habitat we shall examine is the Palustrine environment. This strange word describes places otherwise known as marshes, swamps, bogs and ponds. While each of these wetland types is really a very specific habitat, they generally share certain characteristics such as being relatively small in size, of shallow depth, with no active wave-formed or bedrock shoreline features.

11. Looking first at a freshwater marsh, notice this wetland has open water spaces and the surrounding vegetation is herbaceous or grass-like. Birds, such as the red-winged blackbird and the long-billed marsh wren are familiar in this environment.

12. By contrast a swamp has a smaller area of open water and is covered with woody plants, either trees or shrubs. Animals such as deer and beaver frequent this habitat.

13. Both marshes and swamps begin as open areas of water. Rains erode the surrounding land, bringing soil to be deposited in the still waters. Through time plants and animals live and die in this habitat, adding to a build up of dead organic material. This complex process, called eutrophication, results in the habitat changing over time. This change we call aging or succession.

14. Freshwater marshes and swamps perform an important function in the water cycle. Surface water runoff accumulating in the wetlands is retained during flood periods. Slowly the water is released overland into connecting streams, or seeps into the groundwater layer, replenishing the subterranean reservoirs, called aquifers.

15. As important as these wetlands are, they are quite susceptible to adverse impacts. They are easily drained or filled because they are often small and the water levels are low. Also, the lands sloping into the marsh act as watershed draining into the marshes. When vegetation is removed from the upland slopes, for housing or highways, increased flows, siltation,and contamination from pollutants cause the wetlands to age much faster.

16. Two other Palustrine environments are important to know and understand. The first is a bog habitat. Like marshes and swamps this habitat began with an open water area. However, floating bog plants like sphagnum, cover and hide the water below, causing the area to appear deceptively terrestrial. Lovely Bog laurel and Labrador tea are among the plants found in this wetland. Occasionally cranberries grow in these N.W. bogs. Like the other Palustrine wetlands, bogs are relatively fragile. Humans use the bogs for peat extraction and unfortunately, upon occasion as locations for housing developments.

17. The last Palustrine environment to examine is ponds. They are classified as Palustrine because they tend to be small in size -- less than 20 acres, of very shallow depth, with indefinite edges which are frequently overgrown with reeds and marsh plants. In general, however, this habitat is similar to and supports similar life forms as does the next classification of wetlands, the lacustrine system, or lakes.

18. Typically, larger lakes have extensive areas of deep water and considerable surface wave action. Plants and animals found here have adapted to these conditions. Plants such as cattails and water lilies are often found in the shallow areas of lakes.

19. Lakes and the adjoining terrestrial habitat provide cover, nest sites and food for a variety of wildlife species. Such species include beaver, muskrat and mink, and fish such as Sockeye salmon. These bodies of water are part of a vast chain of wetlands used by many species of migratory birds such as Canada geese, mallards and grebes.

20. Within the watershed, lakes function to contain and slowly release flood waters brought about by heavy rains or melting snows. This water storage helps prevent erosion from occurring downstream. But surface water runoff from heavy rains brings nutrients into the lakes. These nutrients are trapped in the slow moving waters of the lakes and contribute initially to plant productivity and ultimately to the aging of the lake.

21. Streams and rivers bringing nutrients to the lakes make up the part of the watershed called the riverine environment. The riverine system connects the mountain streams and wetlands with the sea. Water is usually flowing through a channel, acting as a force with which plants and animals must deal. The terrestrial community along the edges of wetlands is called the riparian zone.

22. The riparian vegetation near a wetland is determined by what type of wetland it is. In the riverine environment, the grasses and trees on the banks of the channel play an important role in trapping nutrients and providing food energy for the river ecosystem. The shade provided also keeps the water cool.

23. Plants such as algae, aquatic mosses and trees like alder and cottonwood, help insure that the northwest streams and rivers are among the most important wetland habitat types for wildlife.

24. Bird species, such as the great blue heron, the belted kingfisher and eagles and the terrestrial animals like raccoons, mink and beaver use the river environment for food, cover, nesting and resting. Of course the northwest rivers are among the richest producers of fish in the world, particularly the Pacific salmon, trout and steelhead.

25. The place where the river encounters the sea is a special subsection of the watercourse. It is called the estuarine system. The estuary, where the fresh water meets the salt water, is a complex habitat. Tidal forces alternately flood and ebb, influencing the substrate, the plants and the animals, both within the estuary and along its shallow margins.

26. The estuarine environment is a diverse and highly productive habitat. Plants found in this environment must be capable of dealing with the chemistry of the environment. Typically, they must be salt water and/or freshwater tolerant, they need to cope with sediments, chemicals and nutrients brought to the estuary by the rivers and must have a system of carrying air to the part of the plant growing underground. Plants such as pickleweed and arrow weed are found in the salt marsh area, while seaweeds such as enteromorphia are found in the brackish waters.

27. The terrestrial animals of this environment may be similar to those found in other lowland wetlands. However, the animals found in the water have adapted to the salt and freshwater influences. Some, like clams can burrow underground when the environment is hostile. Others, like salmon adapt to the environmental changes. But most significantly, the estuary is where the juveniles of many different species are found. The rich plant productivity of this environment makes it a natural nursery for the young of many commercially valuable fish and shell fish.

28. Perhaps the value of the estuary can never be established. This habitat, like the other wetland habitats described here, has been frequently sought for agricultural, industrial or urbanized development. But we may find the economic value of all the natural wetlands, for fisheries, recreation or wildlife alone, may equal or surpass the market value of the land developers.

EVALUATION

A. A housing developer has located a section of land in the Cascade foothills in which to build 100 houses. At the heart of this land is a swamp of 10 acres. In laying out the development, the developer must consult with experts in various areas to make sure the plans are approved by the housing authority. The following questions are among those the developer must have answered. Your job as the company assistant is to provide the answers and make recommendations:

1. What is a swamp?

   A wetland that has some open water but is generally covered with vegetation. The vegetation is usually woody plants and water tolerant herbaceous plants. Woody plants are either trees or shrubs.

2. What kinds of plants and animals are usually found here?

   quaking aspen
   red alder
   black cottonwood
   willows
   western red cedar
   sitka spruce
   cattail
   black twinberry
   skunk cabbage
   water parsley
   kneeling angelica
   crabapple
   yew
   ducks
   red-winged blackbird
   great blue herons
   wood ducks
   woodpeckers
   bear
   deer
   elk

3. If the water carrying capacity of a swamp is similar to freshwater marshes, how much could this 10 acre swamp be expected to retain during storm?

   The swamp which is capable of accomodating several inches of water depth can store over one million gallons.

4. What is the value of a wetland like this swamp?

   nutrient storage
   aquifer replenishment
   water retention
   habitat for organisms

5. What are the typical means of handling the development of construction sites which have wetland areas?

   Filling, dredging and drawing. The sharper students might even suggest leaving the wetland surrounded by a buffer zone of vegetation.

6. What potential impact have the above mentioned methods on the habitat and the watershed.

   Altering the wetland by dredging, filling, or draining changes the habitat. Indeed many plants and animals may disappear due to the change. Others may replace them.

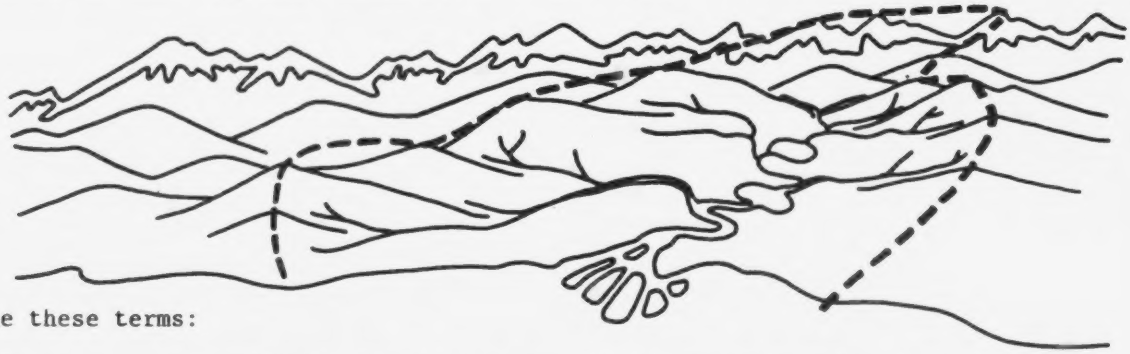
If the water storage capacity is lost there may be flooding down stream in the watershed. There may also be an impact on the replenishment of the groundwater supply.

Students who discussed the protection of the wetland may speak about the benefits of the action.

7. As an employee you are to make recommendations about the development of the site. Your employer wants to make a profit, the community needs the housing and you understand the value of a wetland. What will you recommend?

B. Describe a watershed. Include diagrams and a discussion of component watersystems.

A watershed is an ecological unit in a geographical region - a basin. All the rains and snows that fall in the upland areas eventually flow downhill, combining to make wetlands, small streams and rivers.



C. Define these terms:

Palustrine -	*wetlands in upland areas which have open water areas but no definable edges. Four different habitats are represented: freshwater marshes, bogs, swamps and ponds.*
Lacustrine -	*generally lakes. Areas with large open water areas which have definable edges.*
Riverine -	*Rivers. A fast flowing watersystem.*
Estuarine -	*A wetland area where fresh and salt water meets. A special, and harsh habitat which is highly productive.*
wetland -	*An environment where soils are wet or water saturated. They are characterized by plants that are water tolerant. They are important for their water retention ability.*
eutrophic -	*The build up of nutrients and minerals in a lake or pond resulting in a decrease in oxygen available for animals. It is part of the aging process of wetlands.*
oligotrophic -	*The state of newly formed lakes or ponds that have few nutrients to sustain life.*
aquifer -	*Subterranean water systems, also called ground water.*

NAME ____________________

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Lacustrine -

Riverine -

Estuarine -

wetland -

eutrophic -

oligotrophic -

aquifer -

ACTIVITY 2:
ESTUARIES AND SALT MARSHES
(7 DAYS)

ACTIVITY 2: ESTUARIES AND SALT MARSHES (7 DAYS)

CONCEPTS:

1. An estuary is a semi-enclosed arm of the ocean filled partly with fresh and partly with sea water.
2. Estuaries are complex eco-systems involving interrelated biotic and abiotic factors.
3. The salt marsh is a terrestrial habitat adjacent to the estuary in which the biota is strongly influenced by the estuarine environment.
4. Within Puget Sound are twelve major sub-estuaries. Puget Sound itself is a unique estuary.

OBJECTIVES:

The learner will demonstrate his/her ability to:

1. define and identify estuarine habitats in the Northwest.
2. name 4 types of estuaries according to geomorphological definitions and appropriately classify Puget Sound.
3. describe the net circulation pattern for Puget Sound waters.
4. measure and evaluate the physical and chemical properties of an estuary.
5. inventory and assess the biota of an estuary/salt marsh.
6. assess the ecology of an estuary/salt marsh and be able to describe the nutrient and energy transference cycles.

TEACHER PREPARATION:

1. Read the Teacher Information on "Puget Sound Circulation," "The Flushing Process" and "Plant and Animal Adaptations in the Salt Marsh Estuary."
2. Read through student readings and labs for familiarity.
3. Reproduce class sets of student readings and labs.
4. Make up class sets of "Ecology of a Salt Marsh " packets. Reproduce and cut apart the graphics and include in an envelope. Anticipate making enough packets for every 4 students.
5. Collect materials and equipment for labs -- "Investigations into Estuaries" and "Pass on the Salt Please."

MATERIALS:

Class sets of:
"Ecology of a Salt Marsh"
"Investigations into Estuaries"
"Physical and Chemical Nature of Puget Sound Estuaries"
"Pass on the Salt Please"

See "Investigations into Estuaries" and "Pass on the Salt Please" for specific materials used in each lab.

PROCEDURES:

1. Hand out copies of "Investigation into Estuaries."

   This series of activities is designed to introduce certain chemical and physical properties of estuarine systems to students. Encourage them to form hypotheses about the interaction of salt and fresh water. Ask them:

   "What do you observe happening?" The colored fresh water is on top of the salt water.

"What might be the explanation for this occurrence?" *The salt water is denser than the fresh water and the fresh water simply flows over the top of the salt water.*

"Where in the natural environment might this actually happen?" *Where fresh water runs into salt water - at river mouths.*

"What happens when you introduce the cold salt water?" *The water levels rise and the fresh water is forced over the rim of the dish and out of the basin.*

"How or where might such an action occur in the natural environment?" *Accept any answer, but this is essentially what happens in Puget Sound every year when the cold upwelled waters from the ocean enter the sound over the sill at Admiralty Inlet and flow into the deeper depths of the main basin. The surface waters are carried out to the ocean.*

2. Hand out copies of the student reading "Physical and Chemical Nature of Puget Sound Estuaries." Estuaries and salt marshes have been defined by geomorphology and habitats. This reading helps students to see Puget Sound as an estuary; to understand that Puget Sound is comprised of 12 major estuaries; and to describe estuaries according to the physical and chemical nature and the formation and habitat of estuaries.

3. Hand out the lab "... Pass on the Salt, Please." This lab is designed to develop the idea that because of complexities of the physical and chemical environment, plants and animals found in the estuary are quite remarkable. The daily inundations from the tide and the flooding of fresh water from the river, provide difficult problems for plants.

4. Following this activity, discuss with students why the estuary is such a biologically productive area. Use the teacher information "Plant/Animal Adaptations" for background information.

5. Optional films: Show the film Ecology of a Tidal Slough. This film shows the interrelationships of the organisms that live within the estuary marshlands. Then show the film Billion Dollar Marsh. This film shows what humans are doing with the productive and fertile marshlands. These films are available from the University of Washington.

6. Distribute the student packets "Ecology of a Salt Marsh." Working in groups of 4, have the students construct a food web, using the food web cards, the arrows and the labels from the packets. When the groups are done have them discuss their food webs, explaining what was the primary producer, the first order consumer and so on through the food web.

Typically, students will place the plants (phytoplankton, eel grass, marsh grass, etc.) as the basis for the food web. Now tell them:

"In an estuary/salt marsh, only 10% of the plants are consumed directly. If this is not represented in the food web produced at your table, please correct it to reflect this information."

(NOTE: In the estuary/salt marsh, the food chain is typically based on detritus. Most of the plants die and are decayed. Bacteria then begin feeding on the detritus. Certain zooplankton consume the bacteria and detritus and are in turn consumed by higher order organisms.)

7. Hand out the student reading, "Ecology of the Salt Marsh - Estuary."

Teacher Information

LAB -- INVESTIGATIONS INTO ESTUARIES

Concepts:

1. In an estuary where fresh and salt water meet, there is usually a distinct layering of the water.
2. Incoming cold salt water pushes the top layer out to sea.
3. Mixing of the salt and fresh water occurs as a result of tides and river current.

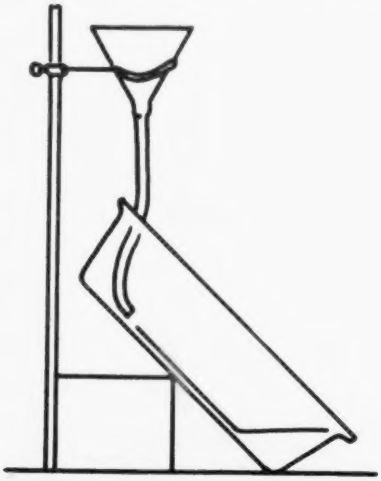
Equipment and materials:
large lunch tray with edges turned up
clear glass loaf baking dish
100 ml tap water at room temperature
100 ml salt water solution at room temperature; 100 ml cold salt water solution
blue dye
red dye
rubber hose with clamp
funnel
small block of wood

Procedures:

1. Place the glass loaf pan in the center of the tray. Place the block of wood under one end so the bottom of the dish is elevated to a 45° angle above the base.

2. Add blue dye to the room temperature fresh water. Pour the water carefully down the side of the elevated edge of the pan. Allow the water to settle.

3. Set up the funnel with the hose attached. (See diagram.) Keep the hose clamped shut until ready. Pour the room temperature salt water into the funnel. With the end of the hose touching the bottom of the pan, slowly release the clamp, allowing the water to flow into the pan.



What do you observe? *The blue colored fresh water floats on top of the clear salt water.*

What might explain what you observed? *The fresh water is "lighter" or less dense than the salt water.*

Consider where this phenomenon might be observed in the natural environment. *At river mouths where the salt water meets the fresh water from the rivers. Also, this occurs where there is heavy precipitation in the ocean.*

4. Clamp the hose closed. Place one end of the hose at the elevated end of the glass pan. Add red dye to the cold salt water. Pour the cold salt water into the funnel and slowly release the water as you did before.

Observe what happens.
The red cold water flows in below the clear salt water forming another layer. The water level elevates and the fresh water (the blue water) flows out over the rim.

Can you think where this phenomenon might occur in Puget Sound?

This question is intended to raise more questions and curiosity. In actuality, this phenomenon is what takes place continually in Puget Sound but with more strength in the late summer when the denser upwelled oceanic water is available in quantity to force the exchange. Cold, upwelled water flows over the sill at Admiralty Inlet. The top layer of water in Puget Sound basin is circulated out to sea.

Can you think of any benefits from this phenomenon?

The cold water brings nutrients and helps to make this region highly productive. Again, this question is one for students to think about.

5. Now, with the end of a pencil or stick stir the water gently. What happens?

The water mixes and the layers will gradually disappear.

How might this result occur in the natural environment?

The daily tidal currents and associated turbulence, the river currents and winds can cause the waters in the estuary to mix.

Consider the estuarine environment. With what difficulties can you see that plants and animals must cope? What happens to a diatom (phytoplankton) that must remain close to the surface to obtain sufficient sunlight for photosynthesis?
During periods of increased fresh water contribution (early spring) the surface water will be more strongly stratified. This helps diatoms remain near the surface and will allow the spring bloom of diatoms (rapid increase in population and organic matter production) to start in the Sound. This is usually around late March and April.

6. Consider the Duwamish River, that flows into Elliot Bay in Seattle. If you were testing for water conditions, what might you expect to find?

The fresh water from the river would flow out and be layered over the salty water of Puget Sound. The amount of layering would be dependent upon the tidal currents, wind and precipitation.

NAME ________________

INVESTIGATIONS INTO ESTUARIES

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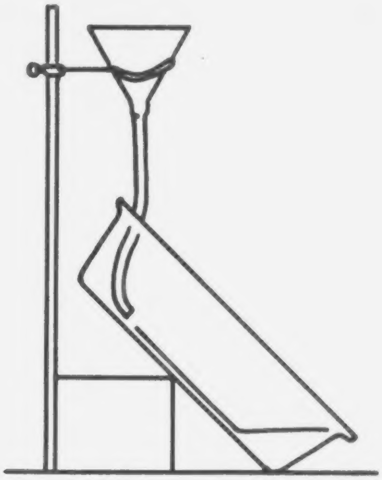

What do you observe?

What might explain what you observed?

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NAME______________________

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Observe what happens.

Can you think where this phenomenon might occur in Puget Sound?

Can you think of any benefits from this phenomenon?

5. Now, with the end of a pencil or stick stir the water gently. What happens?

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PUGET SOUND CIRCULATION, THE FLUSHING PROCESS

As mentioned in the student reading "Physical and Chemical Nature of Puget Sound Estuaries" the water net circulation pattern helps revitalize the estuary. In the Puget Sound estuary the net circulation of water flushes the Puget Sound basin with water inflow at depth and outflow at the surface. This process brings in nutrient rich sea water. Through tidal mixing the nutrients are thereby distributed to the surface layer to promote plant life. Oxygen is distributed from the surface layer to depth by the same process.

We can gain an indication of the ability of an embayment to flush itself based on tidal exchange alone by making a comparison of how much water goes in and out with the tides to how much water there is in the basin on the average.

An embayment that has a large ratio of intertidal volume (the volume of water between the mean higher high water and the mean lower low water) to average volume, discharges a large percentage of its water to the adjacent water body during each ebb tide. If this released water is displaced from the entrance so that on the next rising tide a different water enters the bay to refill it to the high tide level, the bay has excellent flushing properties. Such a location is Gray's Harbor, where the intertidal water volume equals 40 percent of the average water volume.

The recycling of discharged water back into the bay on the rising tide will decrease the flushing ability of a bay due to tidal processes. Or, if a small ratio of intertidal volume to average volume of water enters the bay, then the flushing ability decreases. An example of this is Hood Canal, where the ratio of intertidal water volume to average water volume is much smaller than Gray's Harbor. The flushing rate for Hood Canal is much less.

The net circulation, tidal turbulence and mixing of estuarine waters affect the properties of the water in terms of temperature, salinity, nutrients and dissolved gases. In turn, the water properties dictate the types and numbers of organisms that can survive in the estuary.

To determine the net exchange of water between the ocean and an estuary such as Puget Sound, based on water properties and river contribution, one must make two assumptions. The first assumption is that averaged over many tidal cycles the sea level in Puget Sound doesn't change. This means there is a fixed volume of water in the Sound. Thus, the volume of water added to Puget Sound (by rivers and rain) and in flow at depth when averaged over many tidal cycles, must equal the volume of water that leaves Puget Sound at the surface.

The second assumption is that over time the average salinity of the waters in Puget Sound stays constant. The amount of salt removed from the sound by the seaward flow of surface water which gains salt content on its seaward journey is equalized by the amount of salt carried to the Sound by the incoming ocean waters.

Given these two conditions and the average salt content of the incoming and outgoing water, it is possible to calculate the rate surface water is transported from the estuary to the ocean. This transport is approximately equal to the river contribution plus the required inflow at depth. This rate of surface outflow divided into the volume of the sound yields an estimate of the rate of flushing; how long it would take to empty the Sound or exchange its water volume.

The Flushing Rate of Puget Sound

The exchange of surface waters and the intermediate waters of the entire Sound by this net circulation or transport process is fairly continuous. Calculations based on water and salt budgets show that the flushing time, determined from this net exchange, may be roughly every 100 to 170 days. The denser slower moving deep waters of the basin, which are trapped below the sill depth, may not be exchanged so readily while in some sections of the Sound other processes speed up the exchange.

The exchange of this denser water may require a surge of incoming ocean water in some areas of the Sound. During the summer months off the coast of Washington, the prevailing wind patterns push the surface water away from the shoreline. To replace this volume of water, very dense, cold and salty ocean water is brought up toward the surface. This process is called upwelling. When this dense water rises above the depth of the Strait of Juan de Fuca, its greater density causes it to flow into the Strait at depth. This displaces the less dense existing waters.

Eventually, enough of this dense water accumulates to flow over the sill at Admiralty Inlet. At this point this intruding water is modified by mixing with the outgoing surface water. The density of the resulting mixture is usually greater than the older, resident, deep basin water in the Sound. This causes the entering bottom waters to drive along the bottom of Puget Sound, displacing an equivalent amount of residual water. This pushing of dense water into the Sound to flush out the residual water, occurs in late September or early October. Thus, in terms of flushing some of the deeper basin water, it is replaced only once each year. This annual process is especially evident in the isolated deeper basins of Hood Canal.

Name ________________

PHYSICAL AND CHEMICAL NATURE OF PUGET SOUND ESTUARIES

Estuaries are the most highly productive and complex ecosystems in the Pacific Northwest. It is important to understand the physical and chemical nature of estuaries, and to understand the interractions of both with the biological aspects of this environment. This reading will help define and categorize estuaries according to their physical and chemical nature and their geomorphology (formation and geology). Classifying estuaries is difficult because the habitats are highly diverse.

What is an estuary? In the strictest sense of the definition, an estuary is "a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with fresh water derived from land drainage." One could consider all of Puget Sound as a single estuary meeting the requirements of the above definition. Puget Sound is also a series of estuaries which are maintained by the ebb and flood of the tides and associated with each principal river.

Classifying the Estuary

How does one define an estuary? Perhaps the first step is to define it in terms of geomorphology (the physical setting). This method explains how the estuary basin is formed and gives a limited description of the physical configuration of the basin. The accepted geomorphological descriptions include:

1. The Drowned River Valley (A multi-branched shallow estuary) - is caused by an inundation from the sea. Examples of this type include Chesapeake Bay and the Delaware Bay on the East Coast and Willapa Bay and Grays Harbor on the West Coast.

2. The Coastal Shelf Estuaries (Bar Bounded Estuaries) - are formed behind protective coastal barriers such as barrier islands. Again, these are frequently found on the East Coast and Gulf Coast. Pamlico Sound is an excellent example.

3. The Fault Bays (the Tectonic Process Estuary) - are caused by tectonic movement of the earth's crust, for example, San Francisco Bay and Bodega Bay in California.

4. Fjords and Fjord-like Estuaries - are caused by glaciers which carve steep walled, deep basins with an opening to the sea. These are commonly characterized by a sill at the seaward entrance. (The sill is an underwater barrier which raises up from the sea bottom, but does not break the surface of the water.)

   In the case of fjords, the sill is formed by the glacier. The glacier stops pushing material ahead of it when its snout reaches the open sea and begins to melt. The rock and sand deposited by the glacier accumulate, forming what is called the terminal moraine. If the glacier carved valley is later flooded with sea water this terminal moraine becomes the sill.

Name ________________

Puget Sound is fjord-like, having been carved by a glacier, but the sill, located at Admiralty Inlet, is not the terminal moraine of the glacier. The glacier carving in this case was from the entrance to the head of the sound rather than in the more typical opposite directon. Hood Canal is the most fjord-like channel in Puget Sound.

5. Narrow River Mouths (classical salt wedge estuary) - are caused when the fresh water flow is sufficiently strong to counteract the incoming sea water. The mouths of the Mississippi and Columbia Rivers are such estuaries.

Circulation: A Classification System

The next step in classifying estuaries is to look at the patterns of water circulation. It is important to understand the dynamic interactions that occur in an estuary. First of all is the interaction of the fresh water with the salt water. Consider a number of factors:

1. The rate at which fresh water is added to the estuary due to river discharge and the amount of rainfall that occurs.

2. The tides. Water enters and leaves the estuary each tide cycle. Two important factors are volume and speed of current of tides. Volume is related to the range of the tide (elevation changes between low and high water stands) and the surface area of the embayment. The speed of the current is governed by this volume and the dimensions of the channel through which water volume must flow.

3. The physical configuration of the basin. This refers to how the basin was formed as well as the width and depth of the embayment.

4. The climate, the season, and the prevailing wind patterns.

All of these factors influence the amount of mixing between fresh and salt waters and/or layering of fresh water and salt water. It also influences the circulation.

The way seawater is distributed within the estuary is influenced by the circulation. The patterning of seawater and freshwater distribution can be measured and mapped. From this, four main types of estuaries can be classified.

Dr. Donald Pritchard of Louisiana State University, identified four main types of estuaries based on their pattern of circulation. The first type, Type A, is commonly called the Salt Wedge. It is formed when the incoming salt water, which is denser than fresh water, tries to flow in along the bottom of the basin. The outgoing fresh water, being less dense, flows out the mouth of the river, with sufficient force to push the salt water back and override it at the surface. The water layers become stratified (layered) at the river mouth. The Columbia River estuary is a typical example of a type A estuary. See Figure A for a graphic representation of the salt wedge.

Name ________________

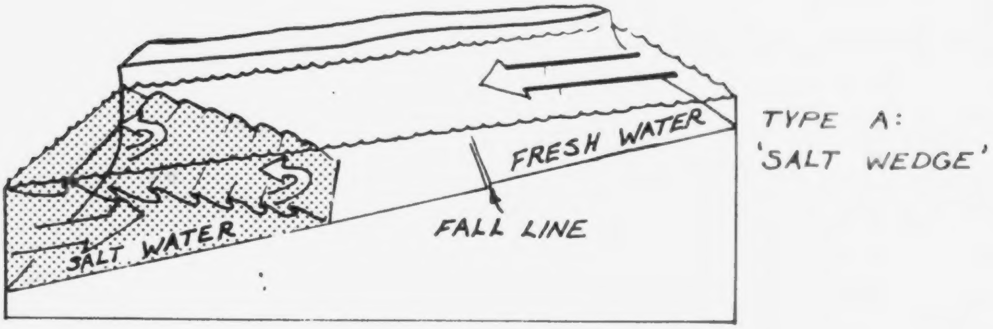

TYPE A:
'SALT WEDGE'
FRESH WATER
FALL LINE
SALT WATER

FIGURE A

This type of estuary is similar to that which you created in the lab experience "Investigation into Estuaries." Type B, a Sloping Boundary Estuary, occurs by adding a little more turbulence from the tidal currents relative to the river flow. Here the mixing between the deeper salt and surface fresh water is greater, due to the increased turbulence and currents. Also the fresh water tends to flow outward along the right side of the river bank (facing seaward) while the incoming salt water hugs the left bank. (This occurs in the northern hemisphere due to the Coriolis Effect). This is represented graphically in Figure B.

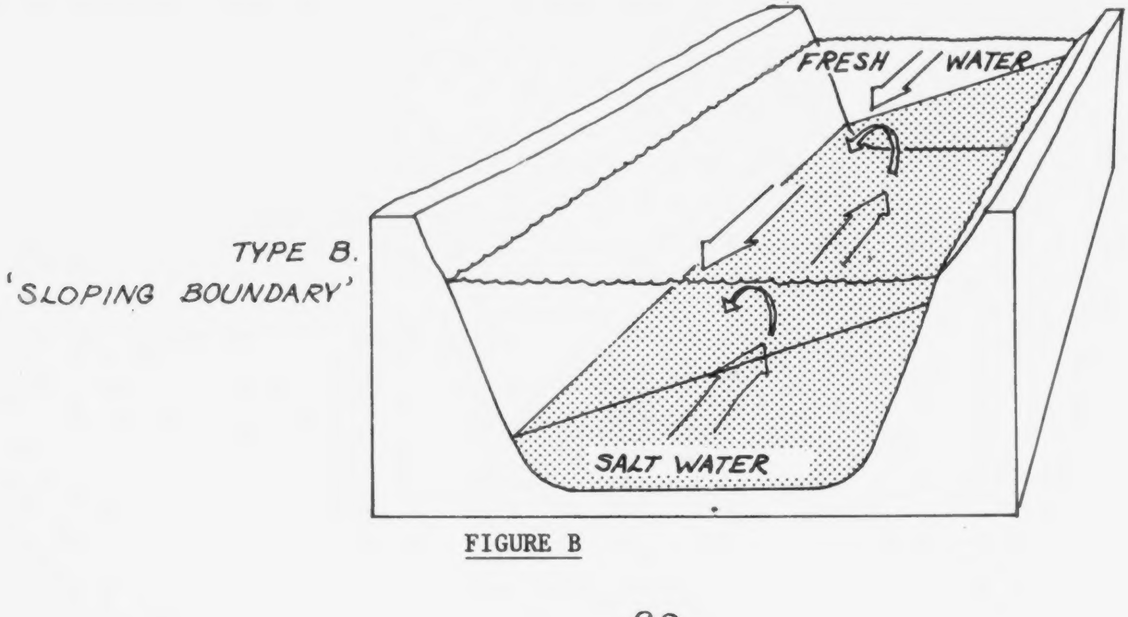

TYPE B.
'SLOPING BOUNDARY'
FRESH WATER
SALT WATER

FIGURE B

Name ________________

The Type C estuary, called the Vertical Boundary type, occurs when the amount of tidal currents and mixing increases even more relative to the amount of fresh water flow. The greater turbulence mixes the water vertically. The stratified layers of fresh water over salt water break down. Consequently, there is relatively little change in salinity from top to bottom. There is a slight change in salinity from bank to bank, and there is a large change in salt content going from the salt ocean to the fresh water river source.

As in the Type B estuary, the south bank facing seaward tends to be of higher salinity concentration than the north. Again this is due to the Coriolis Effect. Figure C is the graphic representation of this type.

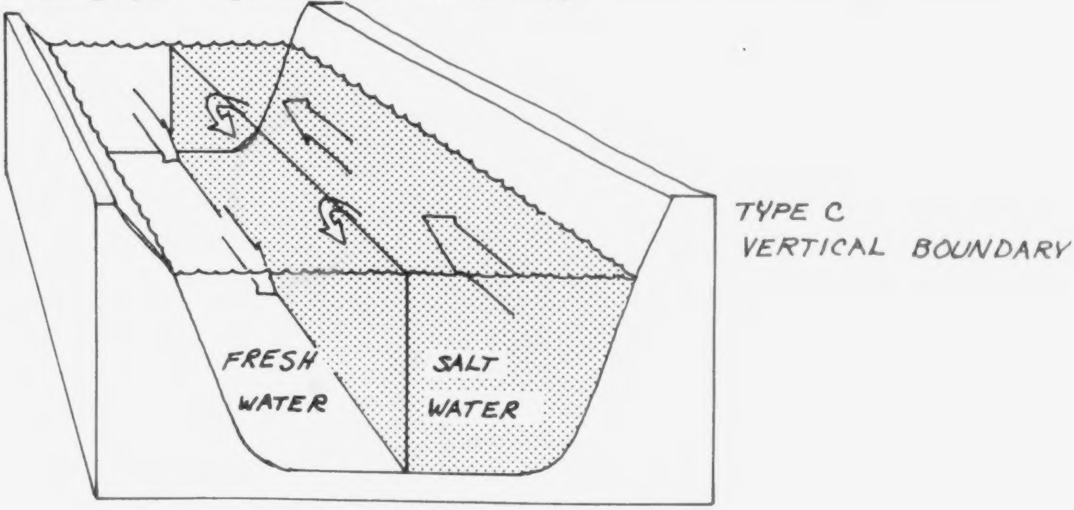
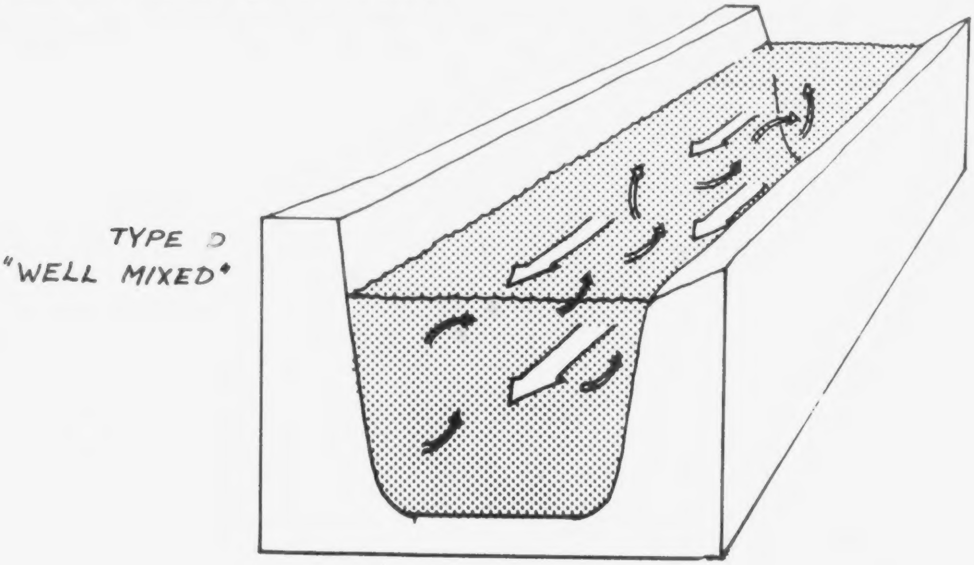


FIGURE C

The last type of estuary, Type D, is called Well Mixed. It is so named because the extreme turbulence causes the salinity of the water to be fairly uniform from top to bottom and cross channel. Such turbulence is caused by large tidal currents. Also the amount of fresh water added to the system is usually small. Figure D represents the well-mixed type of estuary.



Name ________________

Puget Sound as a whole system acts like a Type B estuary. However, within the Puget Sound basin complex some components act differently. Indeed, there are 12 major estuaries in the Puget Sound basin. Consequently, one can find a Type A estuary in places like the mouths of the major rivers, such as the Skagit and the Snohomish rivers. Properties of a Type B estuary may be found at Admiralty Inlet. The salinity distribution through Deception Pass is like that of a Type C estuary. At Tacoma Narrows, the tidal currents are sufficiently strong for it to be classified as a Type D location.

As mentioned earlier, Puget Sound is a fjord-like estuary with a sill at its entrance. As a type B estuary, its water column is relatively stable. Less salty water at the surface overlays the saltier water at depth.

Sea water enters at depth through the Straits of Juan de Fuca and flows over the sill and into the central basin of the Sound. The multitude of streams and rivers flowing into the basin form a freshwater layer that overlays this sea water. Tidal turbulence helps mix the two layers. As a result the surface layer becomes saltier as it moves seaward. The deeper layer becomes less salty as it moves inward. This in at depth and out at the surface is a net flow that occurs and is not to be confused with the daily tidal ebb and flood.

If the system were static (not moving) the sea water would remain at depth while the fresh water remained at the surface. Eventually, the biological processes which occur would cause the water at depth to become depleted of oxygen. Meanwhile, the surface layer would become starved of nutrients. Puget Sound relies on its net circulation and tidal mixing to flush (cleanse) itself and to maintain the productivity level of the estuary. This process helps oxygenate the deeper basin waters.

The consequence of this flushing process is the revitalization of the estuaries at depth. Nutrients and oxygen (which is dissolved in the water) are brought into the estuary system and water from depth which has been partially depleted in its oxygen content is removed.

Within an estuarine environment,different areas can be identified because of the interrelationships between all the factors that enter into creating the estuary. Simply put, there will be areas of water in which it is well mixed and the circulation patterns keep it well flushed. There will be other areas in which little mixing occurs and the oxygen and nutrients become depleted or enhanced. Within this world the bottom surface (the substrate) is also important. The type of substrate, either rocky or sandy or muddy, and the relative amounts of dissolved oxygen and nutrients trapped within the soil make up different zones.

The elevation as related to sea level also enters here, as some biological forms can stand exposure to air in the intertidal zone while others cannot. Depth also becomes important as plant life needs sunlight. In Puget Sound the basin depths can exceed 200m with little area of the Sound devoted to shallow depths. Thus sufficient light is not available to promote photosynthesis in much of the deeper water volume of the Sound. This makes Puget Sound much different than the east coast shallow estuaries where sufficient light penetrates to all depths for photosyntheses. In Puget Sound photosynthesis is limited to the surface layer of the water column which is remote from much of the sea bed. The plant life contributing to the organic matter production in Puget Sound must be planktonic (diatoms) whereas in the shallow estuaries of the east coast bottom dwelling plants play the

Name ________________

principal role. Relatively few areas of Puget Sound support stands of eel grass or attached algae compared to shallow estuaries. This is why it is important to conserve those areas of the Sound having these habitats.

The significance of these differences in the aquatic environment is that they supply the needs of different organisms. Ecologically, a habitat is most successful when it can support a diversity of organisms. The more diversified the environment, the greater chance of supplying the needs of a given species and the greater inherent stability of the system.

LAB - " . . . PASS ON THE SALT PLEASE"

The plants that grow in the estuary have made several adaptations to survive the daily tidal inundations of salt water and/or the periodic flooding of fresh water. It is interesting to note the relative effect of salt water on a freshwater plant compared to a plant which thrives near salt water. A further comparison can be made when a saltwater plant is flooded with fresh water. Such comparisons help make clear the unique character and distribution of plants found in the salt marsh area.

Concepts:

1. The land adjacent to the estuary is called the salt marsh and is subject to many of the stresses due to changes occurring in the estuary.
2. The plants of this habitat have developed adaptations to survive.
3. In different parts of the estuary and salt marsh, different plants and animals are found.
4. Some plants become so specialized for saline environment, their tolerance to fresh water is limited.

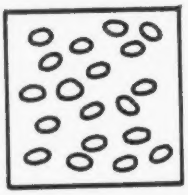
Part A and B

Equipment and Materials:

Elodea (fresh water plant)
Pickleweed (Saltwort) (marsh plant)
Ulva (sea weed)
9% saline solution
Distilled water & droppers
Microscope
Slides and Cover slips
Razor Blade
Paper Towels
Eel grass (optional)
Petri dishes

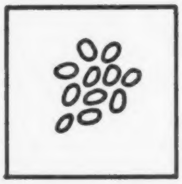
Procedures:

1. Examine the samples of plants. Describe the characteristics of each. Make sketches of each.
2. Place a leaf of the elodea on a slide. Cover with a drop of fresh water. Cover the leaf with a cover slip. Make sure the leaf is quite flat.
3. Observe the elodea under the microscope. Note the position and movement (if any) of the chloroplasts. Chloroplasts are the round, green bodies within the cell. Draw what you see.



4. Now place the edge of the paper towel along the side of the cover slip. This will draw off the fresh water. A drop of saline water placed at the opposite side of the cover slip, will be drawn in to inundate the elodea leaf.

5. Observe the elodea again under the microscope. Note the position and movement, if any, of the chloroplasts. Draw what you see.



6. Repeat this activity but use a thin cross section of saltwort. Make the "before and after" drawings as you did previously.

BEFORE AFTER

7. What conclusions can you make about the relative impact of salt and fresh water on the elodea and saltwort chloroplasts?

Part B

Materials (see Part A)

Procedures:

1. Obtain 2 pieces of the marine algae ulva (sea lettuce) and place one piece in a dish containing fresh water. Place the other piece in a dish with the saline solution.

2. Observe and record any changes you find.
   The ulva in fresh water loses its color.

3. Make slide mounts of each sample. Observe them under the microscope. Record your observations.

4. Summarize your findings from these 2 experiments. Draw your conclusions about the adaptability of salt marsh plants to changes in salt content, salinity.

Part C

Materials:

radish seeds
achellea millefolium (yarrow)
pickle weed shoots
saline mixture 35°/00
planting mix
planting flats
fresh water

Procedures:

1. Obtain several seeds or shoots of each species. In one of the flats plant 2-3 each of the available species. In the second flat plant an equal number of the same shoots and seeds. Label one flat A and one flat B. Place in a sunny location.

2. For the next several weeks water flat A with the saline solution every other day. Be sure to measure the amount of water used. Water flat B with the fresh water every other day. Be sure to use an equal amount of water as for flat A.

3. Observe and measure the growth of plants in each flat.

What can you conclude about the different kinds of plants?

Some plants don't survive in the salt water.

What plants can survive the saline environment? *(the salicornia)*

What can you conclude about the plants of the salt marsh habitat?

NAME ____________________

LAB - " . . . PASS ON THE SALT PLEASE"

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Concepts:

1. The land adjacent to the estuary is called the salt marsh and is subject to many of the stresses due to changes occuring in the estuary.
2. The plants of this habitat have developed adaptations to survive.
3. In different parts of the estuary and salt marsh, different plants and animals are found.
4. Some plants become so specialized for saline environment, their tolerance to fresh water is limited.

Part A

Equipment and Materials:

- Elodea (fresh water plant)
- Pickleweed (Saltwort) (marsh plant)
- Ulva (sea weed)
- 9% saline solution
- Distilled water & droppers
- Microscope
- Slides and Cover slips
- Razor Blade
- Paper Towels
- Eel grass (optional)
- Petri dishes

Procedures:

1. Examine the samples of plants. Describe the characteristics of each. Make sketches of each.
2. Place a leaf of the elodea on a slide. Cover with a drop of fresh water. Cover the leaf with a cover slip. Make sure the leaf is quite flat.
3. Observe the elodea under the microscope. Note the position and movement (if any) of the chloroplasts. Chloroplasts are the round, green bodies within the cell. Draw what you see.

Name ________________

4. Now place the edge of the paper towel along the side of the cover slip. This will draw off the fresh water. A drop of saline water placed at the opposite side of the cover slip, will be drawn in to inundate the elodea leaf.

5. Observe the elodea again under the microscope. Note the position and movement, if any, of the chloroplasts. Draw what you see.

6. Repeat this activity but use a thin cross section of saltwort. Make the "before and after" drawings as you did previously.

BEFORE	AFTER

7. What conclusions can you make about the relative impact of salt and fresh water on the elodea and saltwort chloroplasts?

Part B

Materials (see Part A)

Procedures:

1. Obtain 2 pieces of the marine algae ulva (sea lettuce) and place one piece in a dish containing fresh water. Place the other piece in a dish with the saline solution.

2. Observe and record any changes you find.

3. Make slide mounts of each sample. Observe them under the microscope. Record your observations.

Name ________________

4. Summarize your findings from these 2 experiments. Draw your conclusions about the adaptability of salt marsh plants to changes in salt content, salinity.

Part C

Materials:

radish seeds
achellea millefolium (yarrow)
pickle weed shoots
saline mixture 35°/00

planting mix
planting flats
fresh water

Procedures:

1. Obtain several seeds or shoots of each species. In one of the flats plant 2-3 each of the available species. In the second flat plant an equal number of the same shoots and seeds. Label one flat A and one flat B. Place in a sunny location.

2. For the next several weeks water flat A with the saline solution every other day. Be sure to measure the amount of water used. Water flat B with the fresh water every other day. Be sure to use an equal amount of water as for flat A.

3. Observe and measure the growth of plants in each flat.

What can you conclude about the different kinds of plants?

What plants can survive the saline environment?

What can you conclude about the plants of the salt marsh habitat?

PLANT AND ANIMAL ADAPTATIONS IN THE SALT MARSH - ESTUARY

> "Estuaries are protected embayments strongly influenced by marine waters from the open sea and by fresh water drainage. Flora and fauna must adapt to marine conditions, in which salinities vary greatly due to fresh and salt water mixing. This mixing zone is where tremendous quantities of sediments, nutrients and organic matter are exchanged between terrestrial, freshwater and marine communities. Many organisms benefit from this effect and are dependent on these rich estuarine ecosystems."*

While the physical and abiotic factors define the environment, the diversity and quantity of organisms and its use as a nursery area, become the reason an estuary is such an important habitat. This diversity and complexity of estuarine life can be readily viewed in a salt marsh, which holds the greatest riches of all shoreline in the quantity of plants and animals living there.

In the estuarine system are two subsystems, the subtidal and intertidal. In the subtidal, the substrate is continuously submerged. The types of plants and animals found in the subtidal is dependent upon the texture and composition of the substrate, the physical and chemical nature of the water, solar radiation, water temperature and other factors. Generally, organisms found in the subtidal area of the estuary are well adapted to the marine environment.

In the intertidal region, reaching into the flat adjacent upland areas, is what is known as the salt marsh. A close examination of a salt marsh reveals the relationship between the abiotic factors previously mentioned and the biological. The biological organisms are dependent upon the tidal action and the circulatory patterns of the estuary. The plant organisms take nutrients from the water and produce organic materials to support animal life. Dead and decaying organisms, both plant and animal, also supply the water with nutrients and help deplete the oxygen.

The salt marsh begins as a mud flat at a river mouth. The mud flat is colonized by algae and eel grass. As plants grow and die there is an increasing amount of organic debris. Sediments are brought to the river mouth by the river flow and surface water run off. Sediments and organic debris become the substrate for sedges and grasses which can tolerate having salt water cover their roots at high tide. With increasing build-up some areas are not always tidally covered. Here the plants which are not salt tolerant become the early colonizers.

Nearest the water is a region, often called the low marsh. It is characterized by plants and animals that are most salt tolerant. Further upland is the high marsh. Only infrequently is this region flooded by tidal waters.

* excerpt taken from Coastal Zone Atlas of Washington Land Cover/Land Use Narratives and adapted for this reading

NAME ________________

ECOLOGY OF THE SALT MARSH-ESTUARY

An ecosystem is a unit of plants and animals and their physical and chemical environment in which no one part exists independently of the others. As the food web activity shows, each component ties in with all the other parts. In an ecosystem the food is routes of energy transfer.

Energy in the form of solar radiation is transmitted to the plants of the estuary-salt marsh. The plants absorb this energy and use it to grow and reproduce. Plants, such as sea lettuce, enteromorpha and eelgrass use nutrients brought in by the tide and the river to promote the high productivity characteristic of estuaries. In the case of Puget Sound with its great depths, diatoms are more important as primary producers than are benthic (bottom) plants.

Eugene Odum, a well-known ecologist, studies Georgia salt marshes. He determined that the marsh produces 10 tons of organic matter per acre. This compares to hayfields which produce an average of 4 tons per acre annually, or crop harvest such as wheat which yields 1½ tons per acre. As a side point, it should be realized that the amount of organic matter is total tonnage. Most of the organic matter produced in field crops is either consumed directly by humans or is only 1-2 steps away on the food chain. The organic matter in the salt marsh is not usually consumed by humans. In fact, humans may be several steps away on the food chain. Each step away from the primary producer results in an 80-90% loss of energy. Therefore, while salt marshes are incredibly productive they may not yield as much to humans directly.

This marsh plant productivity has two results. First of all, the plants are eaten, transferring their energy along the food chain. However, only about 10% of all the marsh plants are grazed directly. Most of the plants die, fall into the water and are broken down. The second result of this enormous plant productivity is what happens to the plants that are broken down. Some of the organic debris and the bacteria decomposing it are consumed by micro-organisms, crabs, larvae of insects, mussels, clams, and other consumers. The remainder of the organic debris builds up to form the substrate for the salt marsh.

The development of the salt marsh continues. Plants which can survive occasional tidal flooding colonize the built up substrate. Some of those plants are consumed directly, but most fall into the water to add to the build up or to be consumed.

The plants of the estuary and salt marshes are consumed by animals which are often preyed upon by other animals. These animals may be fish or invertebrates or birds or mammals. The following diagram and list of organisms will be helpful in knowing the ecology of this habitat type. (See Appendix: Salt Marsh and Estuarine Organisms.)

As the lists indicate, the species of plants and animals found are often quite specific to the type of substrate and salt water exposure. Just as some plants and animals can tolerate only a specific range of salinity or temperature, the same can be true for the type of substrate. Some plants and animals require a rocky bottom to attach to, some burrow into sand or mud. Some animals consume only those organisms found in each of those habitats. The whole range of physical, chemical, geological and biological factors are important to understand the whole ecology of the salt marsh and estuary.

Besides being one of the most highly productive ecosystems, the estuary also serves an important function in the hydrologic and nutrient cycles. The estuary works as a flood control mechanism. The delta lands of the salt marsh can absorb the flooding from storm waters. The spongy nature of the marsh allows the water to seep back into the ground and back into the water system.

An equally important function of the estuary is as a pollution filtration system. The plants and the root systems hold sediments brought by river flooding. Also brought by the river system are nutrients, pesticides, heavy metals, and other chemicals and pollutants. The plants take up these nutrients and pollutants, helping keep the waters clean. However, while the nutrients help promote plant growth, the pollutants taken up can enter the food chain. The deposition of fine sediments in the marsh can also trap chemicals in the substrate that are absorbed on the sediment particles.

Salt marshes are important buffers for cliff or bluffs, preventing erosion. They also can absorb waves and currents and hold solar heat, moderating the climate. Marshes are also valued for recreation, education or simply esthetics.

In all, the estuarine ecosystem is a fascinating environment, worthy of additional research and study.

Appendix: SALT MARSH AND ESTUARINE ORGANISMS

Plants of a Salt Marsh

1. Rumex crispus
2. Achillia millefolium
3. Aster
4. Elymus mollis
5. Elymus arenerius
6. Hordium jubatum
7. Atriplex patula
8. Cotula coronopifolia
9. Plantago maritima
10. Distichlis spicata
11. Salicornia herbacea
12. Triglochin maritima
13. Spergularia maritima

CHARACTERISTIC SPECIAL - MUD HABITAT

1. Mammals
    a. Harbor Seal

2. Birds
    a. Gulls
    b. Canadian Goose
    c. Mallards
    d. Pintails
    e. Loon
    f. Widgeon
    g. Geese
    h. Great Blue Heron
    i. Brants
    j. Sandpiper
    k. Yellowlegs
    l. Dowitcher
    m. Western Grebe

3. Fish
    a. Salmon (juv.)
    b. Surf Smelt
    c. Herring (juv.)
    d. Sandlance
    e. Buffalo Sculpin
    f. Pacific Staghorn Sculpin
    g. Tide Pool Sculpin
    h. Shiner Perch
    i. Three Spined Stickleback
    j. Black Cod
    k. CO Sole (juv.)
    l. Starry Flounder
    m. English Sole (juv.)
    Spiny Lumpsucker- (present but not illustrated)

4. Crustaceans

    Shrimp
    a. Hump Shrimp
    b. Coonstripe Shrimp
    c. Dock Shrimp
    d. Mud Shrimp

    Crabs
    e. Red Rock Crab
    f. Dungeness Crab
    g. Purple Shore Crab

    Tanadacean
    h. Leptochelia

5. Molluscs

    Clams
    a. Shoft Shell Clam
    b. Bent Nose Macoma
    c. Inconspicuous Macoma
    d. Transenella Tantilla

    Snails
    e. Turban Snail (Phytia)
    f. Turban Snail (Assiminea)
    g. Bubble Shell

6. Worms
    a. Bamboo Worm
    b. Lug Worm
    c. Armandia brevis
    d. Capitella capitat

7. Algae
    a. Sea Lettuce

8. Higher Plants
    a. Sand spurry
    b. Pickleweed
    c. Salt grass
    d. Wild oats
    e. Cattail
    f. Eel grass

CHARACTERISTICS SPECIES - ROCKY AND SANDY BEACH - MIXED HABITAT

1. MAMMALS
   a. Harbor Seal

2. BIRDS
   a. Eagles
   b. Gulls
   c. Dabbling Ducks
   d. Sand Piper
   e. Yellowlegs
   f. Dowitchers
   g. Great Blue Heron

3. FISH
   a. Salmon (juv.)
   b. Surf Smelt
   c. Sandlance
   d. Herring (juv.)
   e. Three Spine Stickleback
   f. Shiner Perch
   g. Striped Perch
   h. Buffalo Sculpin
   i. Pacific Staghorn Sculpin
   j. Starry Flounder (juv.)
   k. Tubesnout
   l. Sand Sole (juv.)

4. CRUSTACEANS
   a. Cumaceans
   b. Amphipods - (1) Caprellid
      (2) Gammarid
   c. Tanadacean
   d. Isopods
   e. Ostracods
   Blue Shrimp
   Dungeness Crab

5. MOLLUSCS
   Clams
   a. Soft Shell Clam
   b. Bent Nosed Clam
   c. Little Neck Clam
   d. Transenella Tantilla

6. WORMS
   Polychaetes
   a. Mediomastus ambiseta
   b. Platynereis bicanaliculata
   c. Exogone
   d. NEMATODES
   e. NEMERTEANS

7. ECHINODERMATA
   a. Brooding Sea Star

8. ALGAE
   a. Agardhiella
   b. Sea Lettuce
   c. Entermorpha

9. COLENTERATA
   a. Plumed Sea Anemone
   b. Brooding Sea Anemone

CHARACTERISTIC SPECIES - SAND HABITAT

1. MAMMALS
   a. Harbor Seal
   b. River Otter

2. BIRDS
   a. Gulls
   b. Black Brant
   c. Common Terns
   d. Great Blue Heron
   e. Sand Pipers
   f. Crow
   g. Ruddy Turnstones
   h. Plovers

3. FISH
   a. Capelin
   b. Surf Smelt
   c. Salmon (juv.)
   d. Pacific Sandlance
   e. Pacific Staghorn
   f. Pacific Staghorn Sculpin
   g. Shiner Perch
   h. Striped Perch
   i. Gunnels
   j. Sand Sole
   k. Dover Sole
   l. English Sole (juv.)
   m. Starry Flounder (juv.)
   n. Pacific Tomcod (juv.)

4. MOLLUSCS
   Clams
   a. Sand Clam
   b. Bent-Nosed Clam
   c. Heart Cockle
   d. Little Neck Clam
   e. Butter Clam
   f. Gaper Clam
   g. Geoduck

   Snails
   f. Nudibranch
   g. Sea Slug
   h. Chink Shell
   i. Moon Snail

5. CRUSTACEANS
   a. Red Rock Crab
   b. Kelp Crab
   c. Shrimp
   d. Caperellids
   e. Sand fleas
   f. Leptostocans
   g. Cumaceans
   h. Idotea
   i. Cirolan kincaide

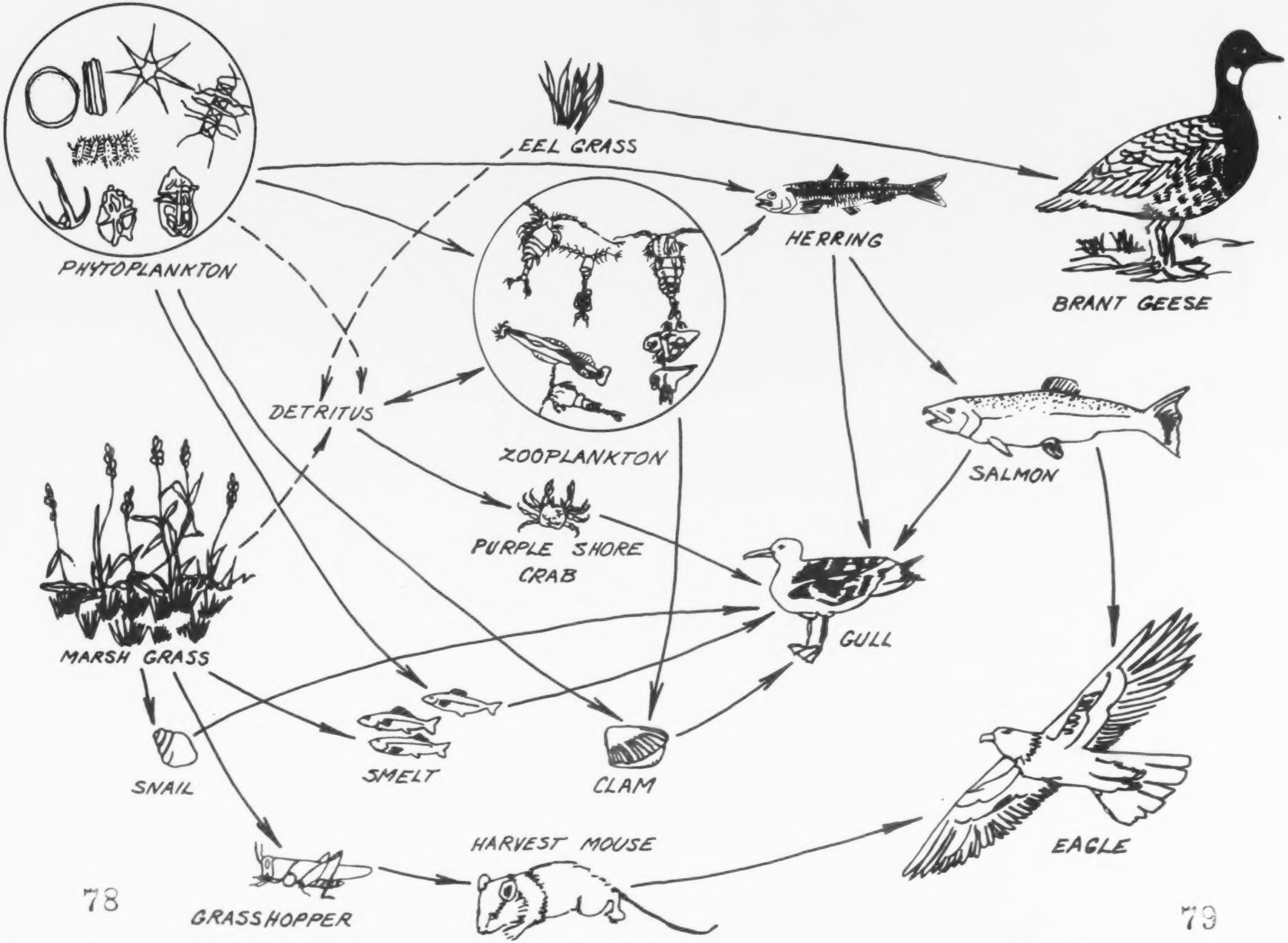
6. ECHINODERMS
   a. Sand Dollar
   b. Burrowing Sea Cucumber
   c. Sunflower Star (Pycnopodia)

7. COELENTERATES
   a. Brown Sea Anemone
   b. Brooding Sea Anemone

8. WORMS
   a. Glycinda picta
   b. Syllis
   c. Scoloplos
   d. Nephyts
   e. Oligochaeta

9. ALGAE
   a. Sea Lettuce
   b. Red Algae

10. HIGHER PLANTS
   a. Eel Grass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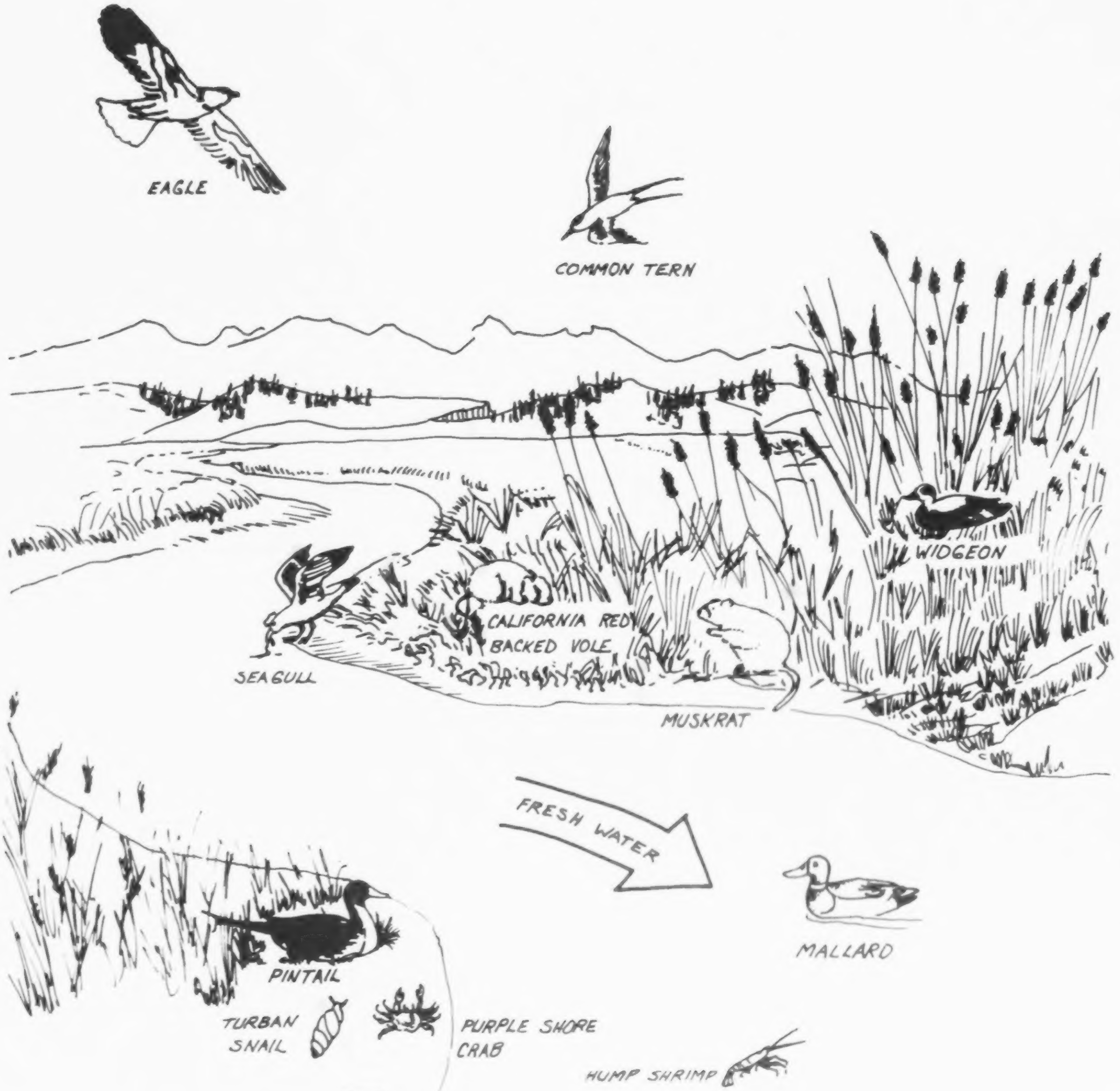
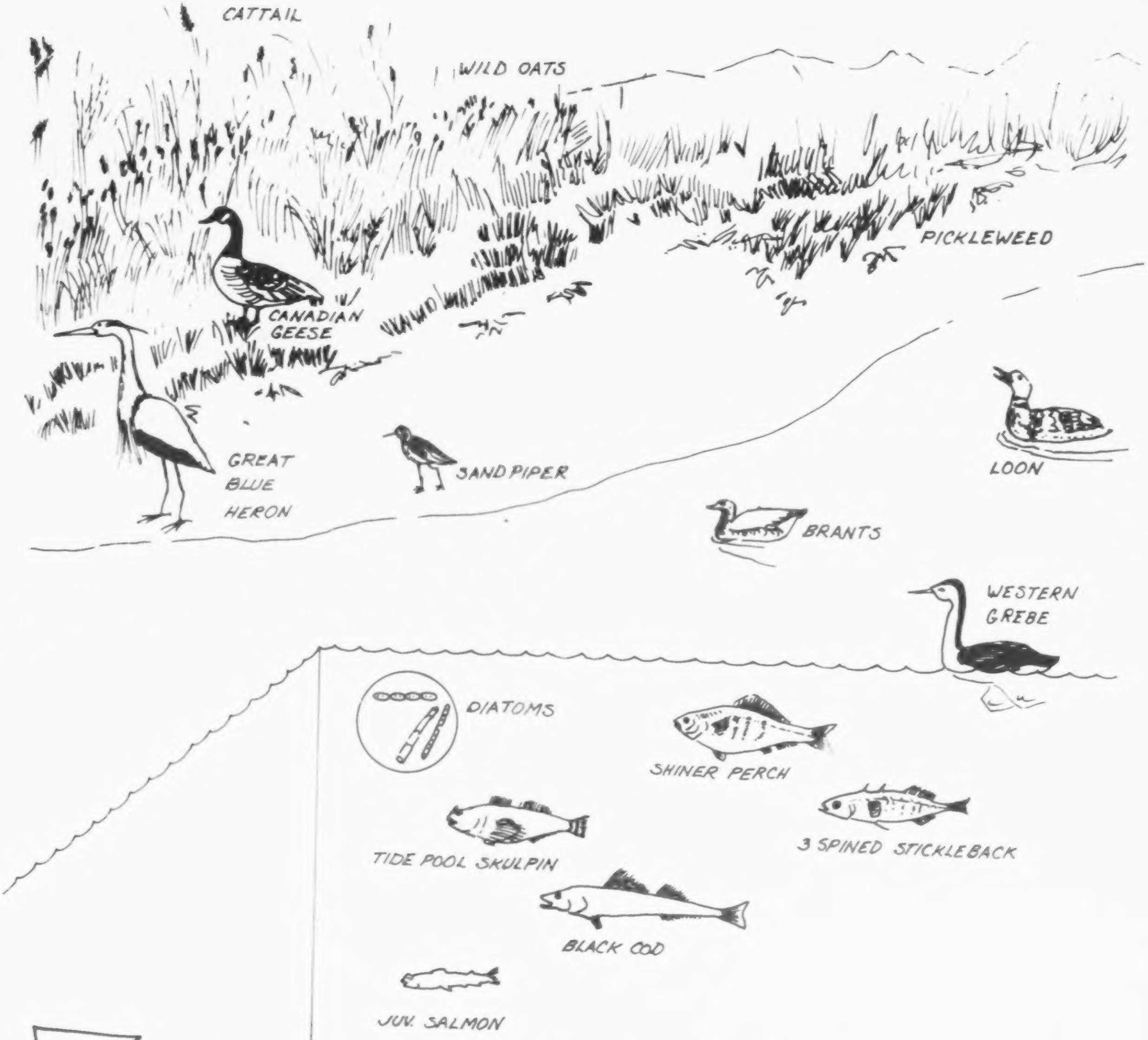
EEL GRASS
HERRING
BRANT GEESE
ZOOPLANKTON
DETRITUS
SALMON
PURPLE SHORE CRAB
MARSH GRASS
GULL
SNAIL
SMELT
CLAM
HARVEST MOUSE
EAGLE
GRASSHOPPER


EAGLE
COMMON TERN
WIDGEON
CALIFORNIA RED BACKED VOLE
SEAGULL
MUSKRAT
FRESH WATER
MALLARD
PINTAIL
TURBAN SNAIL
PURPLE SHORE CRAB
HUMP SHRIMP
SOFT SHELL CLAM
LEPTOCHELIA
LIMPET
COONSTRIPE SHRIMP
CLAM


CATTAIL
WILD OATS
PICKLEWEED
CANADIAN GEESE
GREAT BLUE HERON
SANDPIPER
LOON
BRANTS
WESTERN GREBE
DIATOMS
SHINER PERCH
3 SPINED STICKLEBACK
TIDE POOL SKULPIN
BLACK COD
JUV. SALMON
SALT WATER
SEA LETTUCE
RED ROCK CRAB
EEL GRASS
DUNGENESS CRAB

FOOD WEB CARDS (these are drawings)

Plants

cattails
salicornia
arrow
eel grass
salt marsh plants (sedge)
sea lettuce
enteromorph

Mammals

otter
townsend vole
(meadow mice)
deer
elk

Birds

breat blue heron
gull
eagle
brant geese
falcon
dunlin
marsh hawks
red winged blackbirds

Fish

salmon
starry flounder
sculpin
herring

Mollusks

butter clam
mussels
snails

Worms

polychaete worms

Arthropods

dungeness crab
barnacle
amphipods
shrimp

Reptiles & Amphibians

red legged frog
garter snake

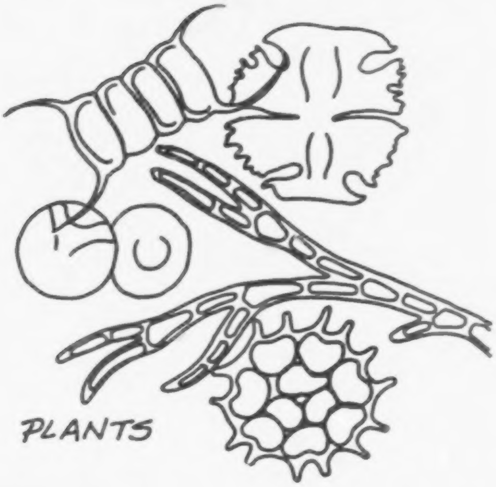
Bacteria

Zooplankton

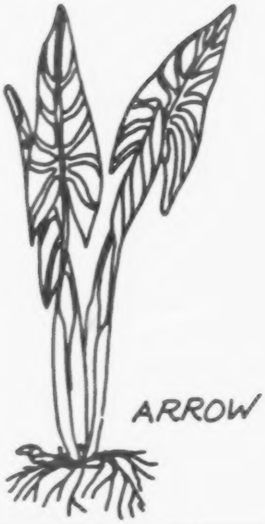
Echmoderms

sea urchins
sea stars

Phytoplankton



PLANTS



ARROW WEED

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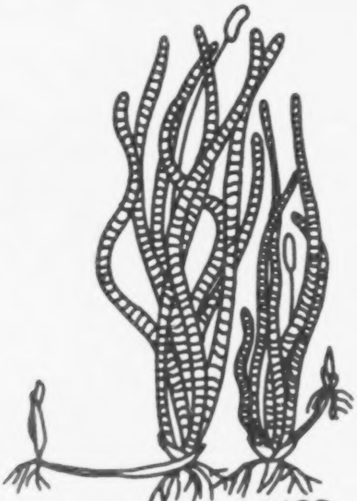
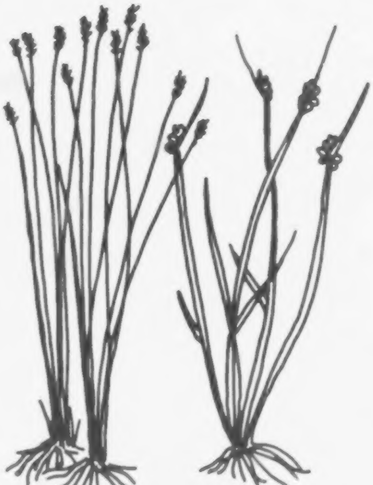


EEL GRASS



SEDGE

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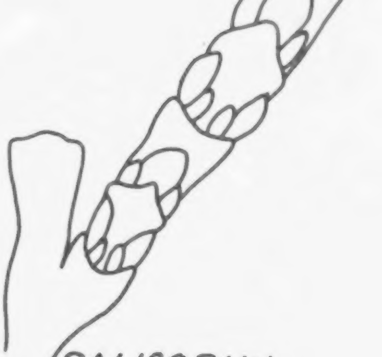
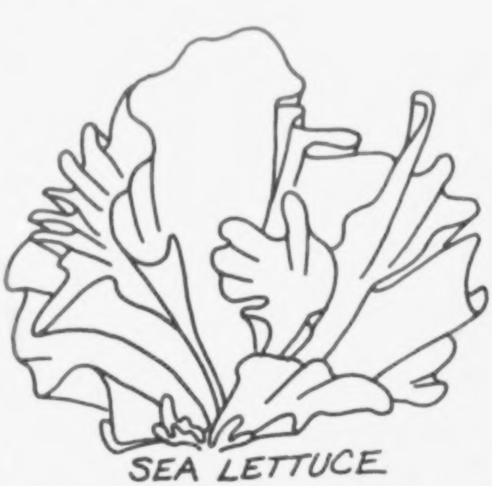


SALICORNIA



SEA LETTUCE

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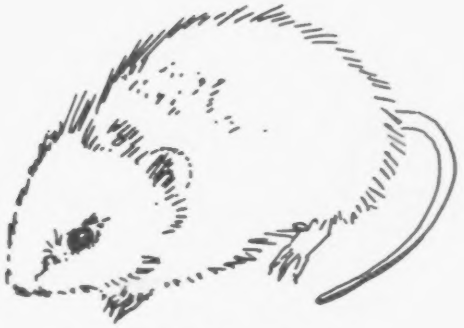
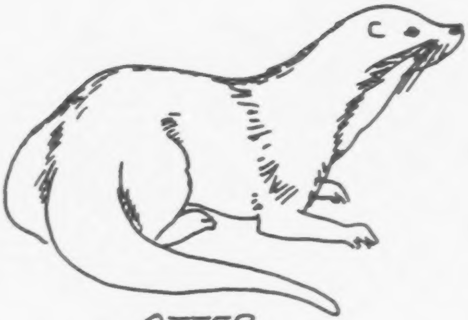


TOWNSEND'S VOLE



OTTER

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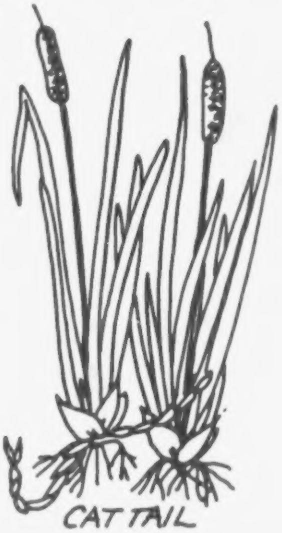
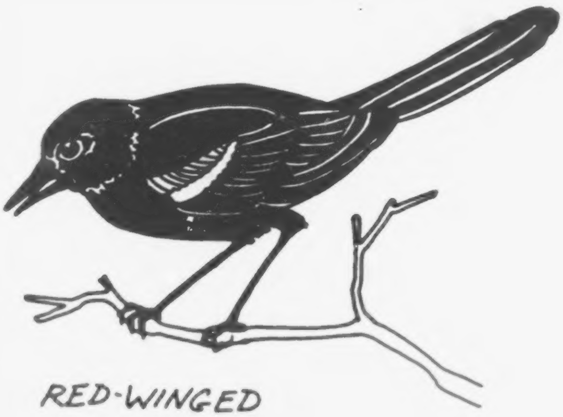


CAT TAIL



RED-WINGED
BLACK BIRD

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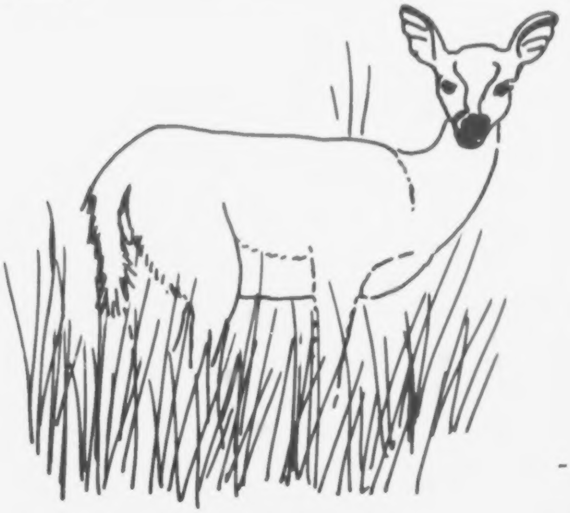

DEER

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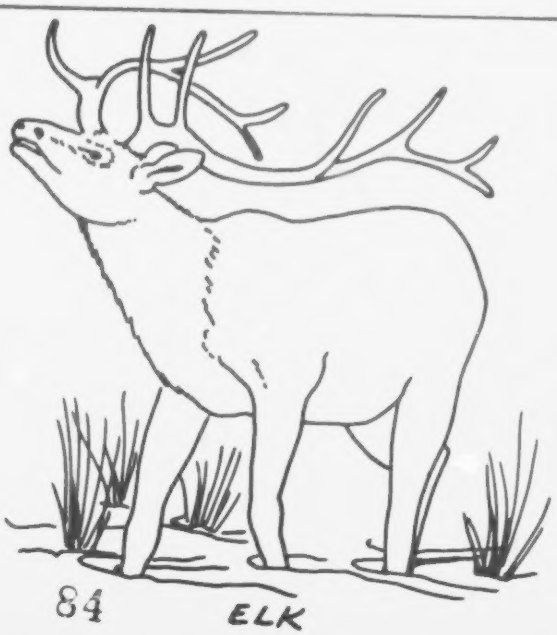
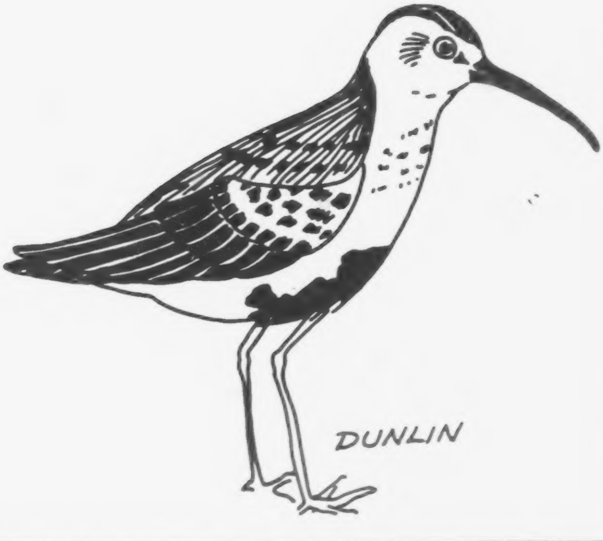
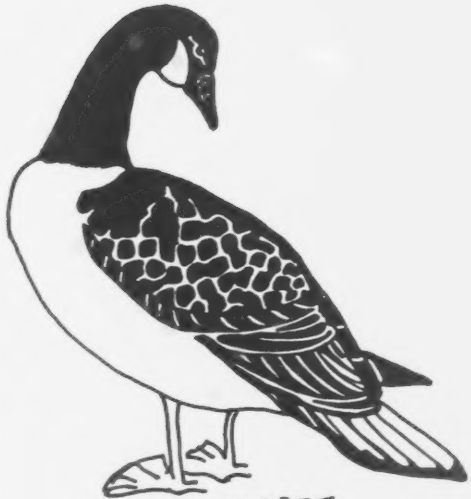


ELK


DUNLIN


BRANT GOOSE

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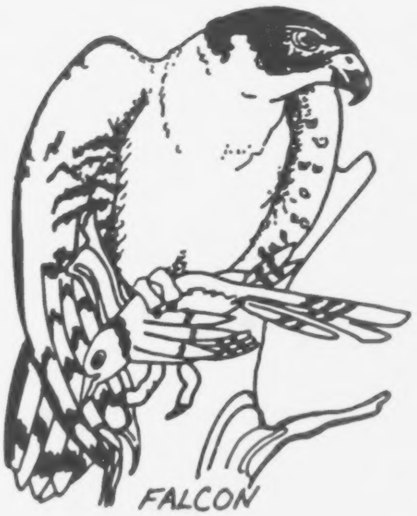
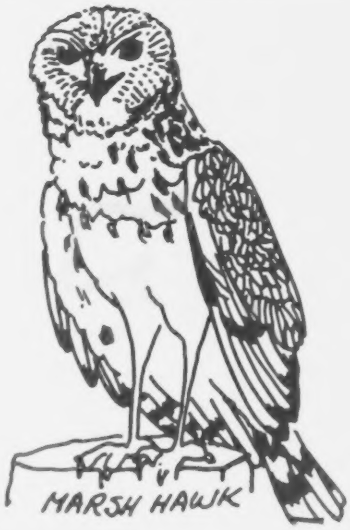
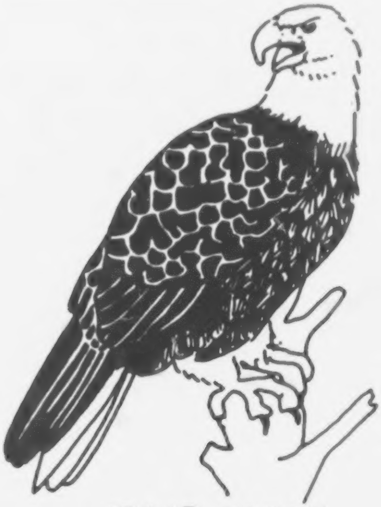
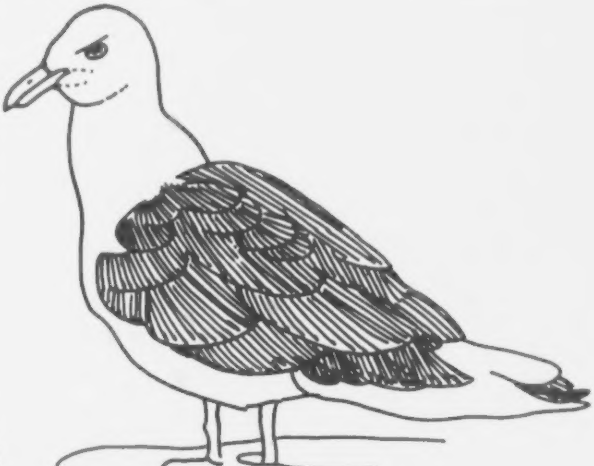

FALCON


MARSH HAWK

CUT HERE


BALD EAGLE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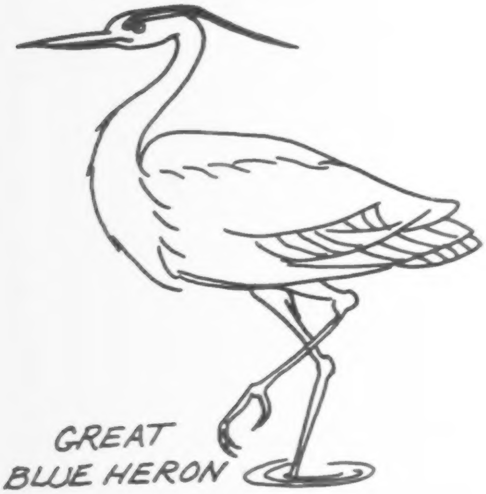
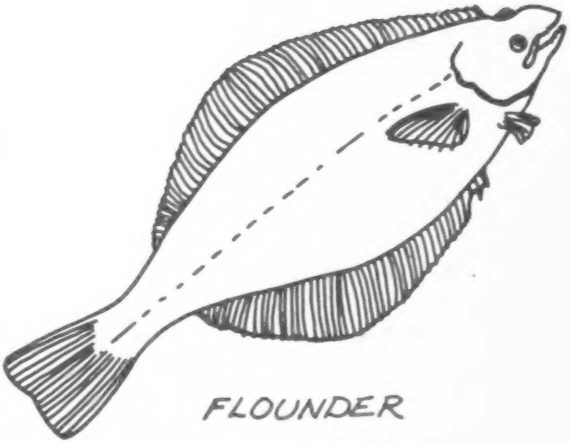
GULL



GREAT BLUE HERON



FLOUNDER

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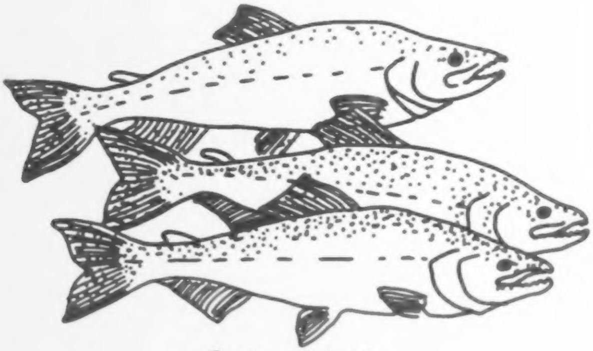
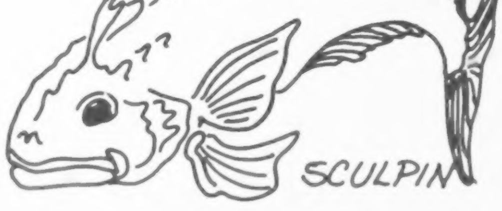


CHINOOK



SCULPIN

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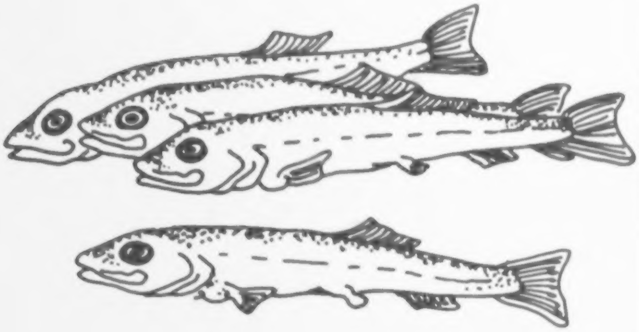
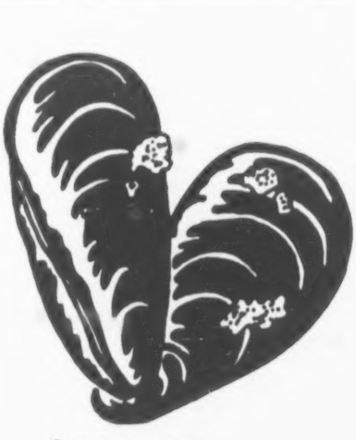
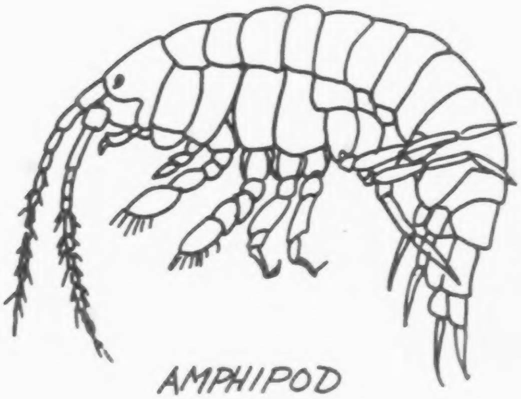


HERRING

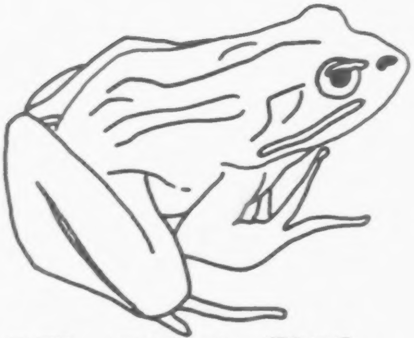


MUSSELS

CUT HERE

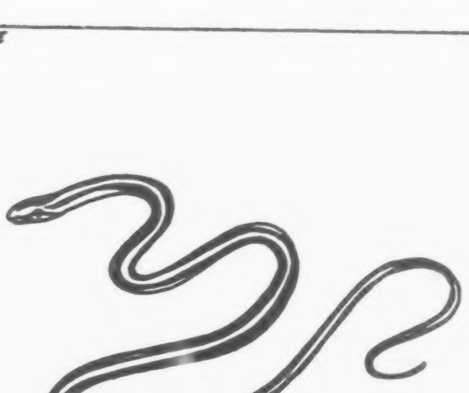


AMPHIPOD

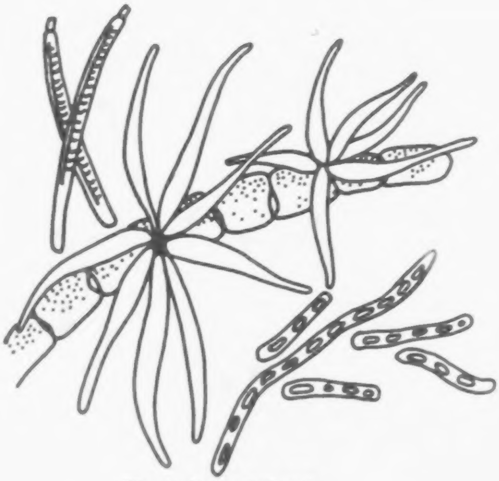


RED-LEGGED FROG

CUT HERE

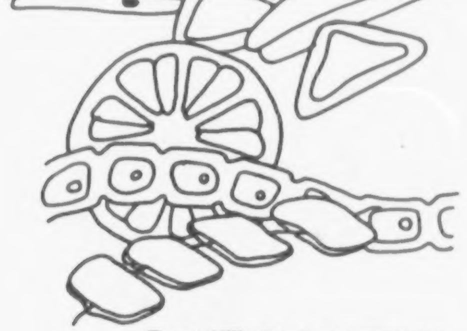


GARTER SNAKE



BACTERIA

CUT HERE



PHYTOPLANKTON

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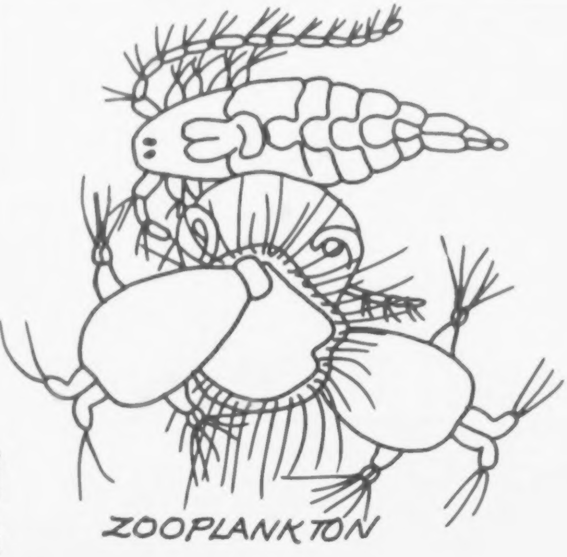
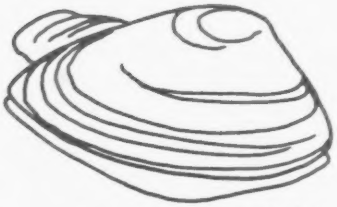
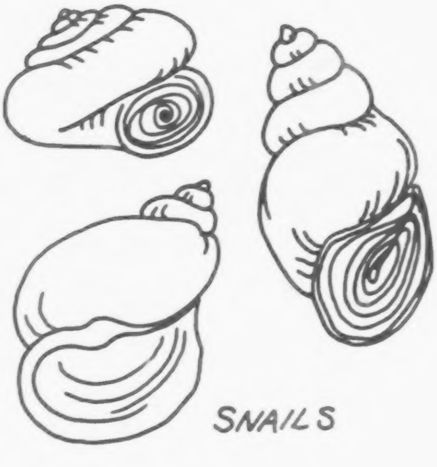


ZOOPLANKTON



BUTTER CLAM



SNAILS

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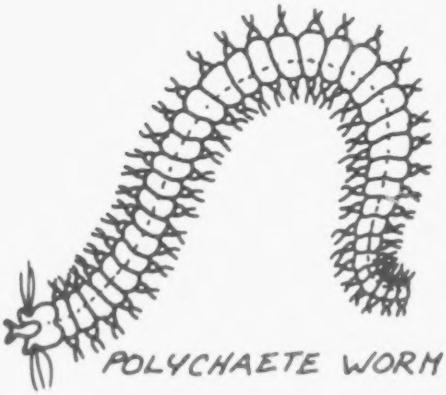
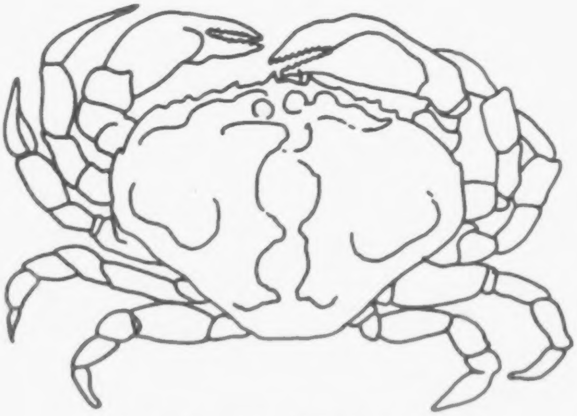
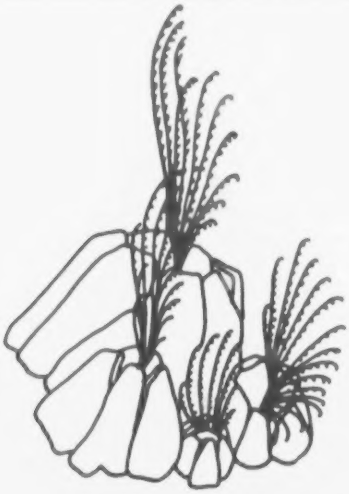


POLYCHAETE WORM



DUNGENESS CRAB

CUT HERE



BARNACLES

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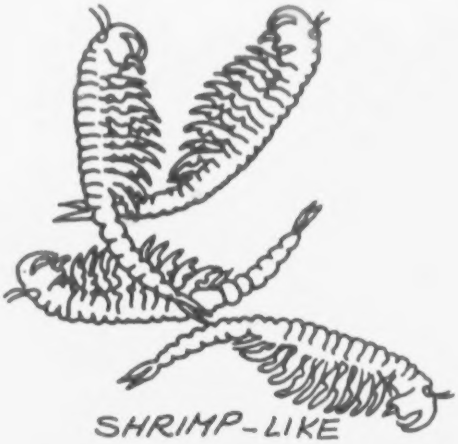
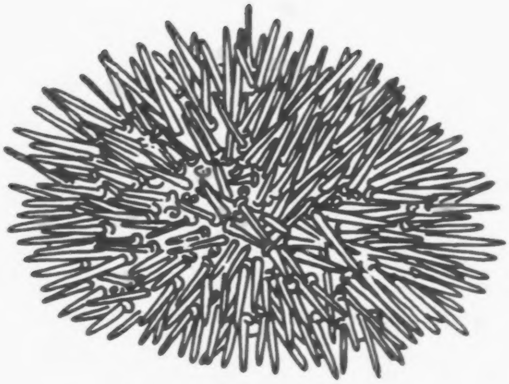
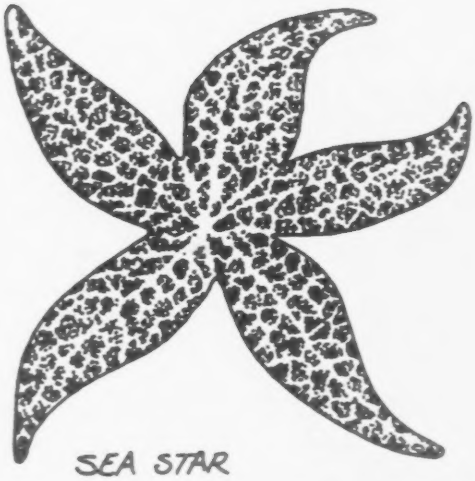


SHRIMP-LIKE ANIMALS



SEA URCHIN



SEA STAR

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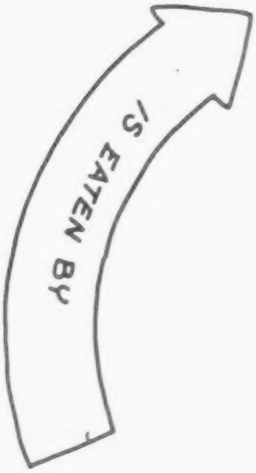
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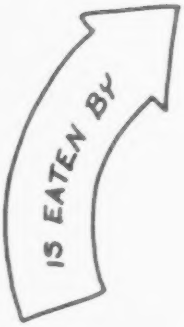
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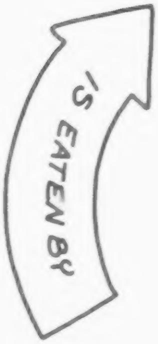
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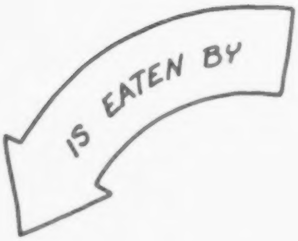
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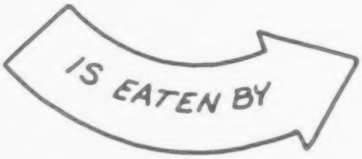
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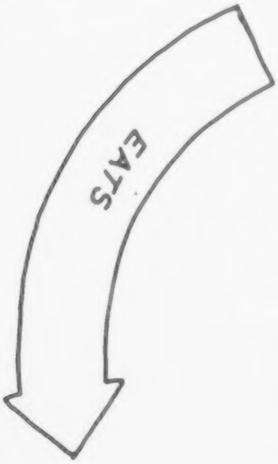
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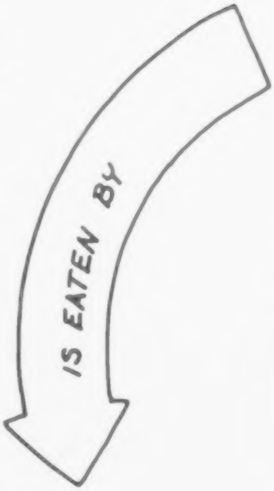
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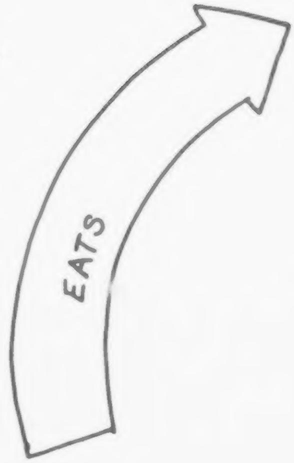
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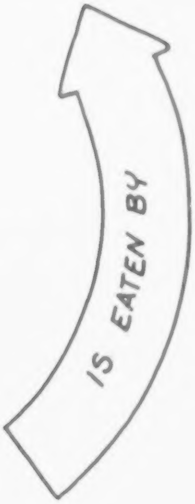
EATS

IS EATEN BY

DECAYS

DECAYS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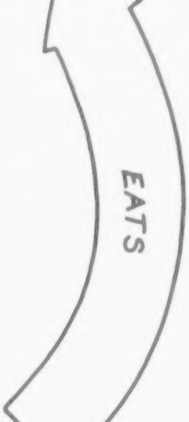
DECAYS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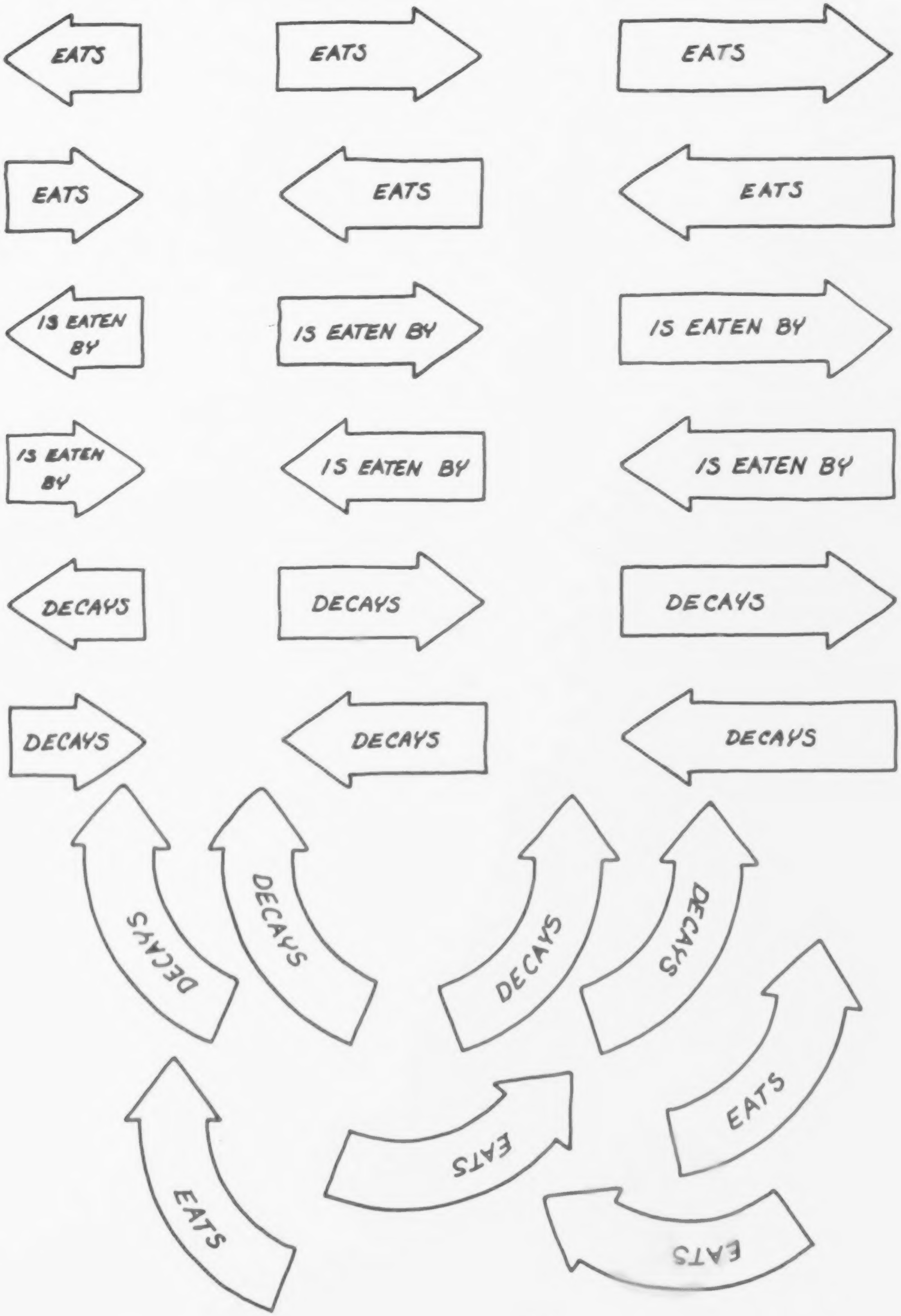
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ACTIVITY 3:
FIELD INVESTIGATIONS AND WETLAND INVENTORY
(2-10 DAYS)

ACTIVITY 3: FIELD INVESTIGATIONS AND WETLAND INVENTORY (2-10 DAYS)

CONCEPTS:

1. Different species of plants and animals are found in different habitats based on abiotic and biotic factors. Wetlands are important habitats for plants and animals.
2. Plant communities can be analyzed and the relative importance of each species determined quantitatively: presence, abundance, frequency and dominance.
3. Abiotic factors, such as the amount of dissolved oxygen, temperature, pH, salinity and nutrients influence the habitat and types of plants and animals.
4. Birds can be excellent subjects for ecological studies for many reasons:
   - They are common year round.
   - There are usually many species.
   - They have fascinating behavior patterns.
5. Animals are more difficult to spot, yet evidence of existence is often readily observed (seen, discovered)
6. Mapping and profiling a site provide a data base to inventory, survey and analyze vegetation and animal life.

OBJECTIVES:

The learner will demonstrate his/her ability to:

1. use measuring skills to evaluate wetlands.
2. survey and inventory wetlands.
3. assess and evaluate impacts to wetlands.

TEACHER PREPARATION:

1. Reproduce class sets of the Field Investigations and Field Data Sheets:
   "Vegetative Analysis"
   "Survey of the Wetlands"
   "Chemical/Physical Analysis"
   "Dissolved Oxygen in Water"
   "pH of Water"
   "Carbon Dioxide in Water"
   "Plant and Animal Indicators of Water Quality"
   "Bird and Animal Sightings"
2. Prepare materials for teams for each of the investigations. See the individual sheets for the specific materials.

MATERIALS:

1. Class sets of:
   "FIELD INVESTIGATION: Survey of the Wetland"
   "WETLANDS INVENTORY"
   "FIELD INVESTIGATION: Vegetative Analysis"
   "FIELD DATA SHEET: Vegetative Analysis"
   "FIELD INVESTIGATION: Bird and Animal Sightings"
   "FIELD INVESTIGATION: Chemical/Physical Analysis"
   "FIELD DATA SHEET: Chemical/Physical Analysis"
   "Dissolved Oxygen in Water"
   "pH of Water"
   "Carbon Dioxide in Water"
   "Plant and Animal Indicators of Water Quality"
2. Quadrat - use a rigid square form for which the area is known. Coat hangars bent into shape are useful. The students can calculate the area.

3. Field Guides like:
   "Wild Flowers of Marsh and Waterways," Lewis Clark;
   "Wild Flowers of North America," Audubon;
   "Wetlands Plants of King County, and the Puget Sound Lowlands," King County Planning Division.
   "Guide to North American Birds," Audubon;
   "Beach Profiles and Transects," ORCA, Pacific Science Center;
   "Marine Biology Field Trip Sites," ORCA, Pacific Science Center;
4. Equipment for every team of three students:
   . map of the area
   . nail
   . pencil
   . 5 foot tall stick
   . 1 piece of string: 10 inches
   . clipboard
   . sighting pole
   . range pole
   . protractor
   . lab book
   . graph paper
   . binoculars
   . thermometers
   . 2 meter sticks
   . level
   * Hach (or LaMotte) water and soil test kits or use the specific chemicals for specific tests as identified in the teacher/student information sheets "Dissolved Oxygen in Water," "pH of Water," and "Carbon Dioxide in Water"
5. . ORCA -"Beach Profiles and Transects"
   . ORCA -"Marine Biology Field Trip Sites"

PROCEDURES:

1. This activity focuses on field analysis of wetlands. Students are encouraged to investigate wetlands in depth and begin to analyze the functions and impacts of wetlands by quantifying their findings. These basic skills can be equally applied to estuaries and salt marshes as well as to freshwater wetlands, often called bogs and swamps. In fact, students are often the most familiar with the environment near the school and will be able to tell you where 'wetlands' are. If you wish to visit a freshwater wetland and you are not familiar with the area, contact the County Resource Planning Board. In King County, the Division of Resource Planning is currently inventorying all of the wetlands in the country. They may be able to direct you to a wetland area that would have easy public access.

2. Divide the class into teams and have them complete the investigations. Upon returning to the classroom have them compile the data, and make individual statements of analysis.

   NOTE: Field data can be quite variable, depending on the location, the season, and the particular day the assessment was conducted. For that reason, it may be useful to return to the site more than once. Also, because of the variables, have students make notations about what they observe during their visit. Field data is often difficult to ascertain. In spite of trying to be consistent in quantifying the data, it sometimes becomes a "judgement call." Accept this.

3. When students have conducted their field investigations, have them fill out the "Wetlands Inventory." This inventory was adapted for student use from the actual inventory form developed by King County Resource Planning task force. The inventory form and the subsequent field inventories of wetlands in King County was a project initiated in 1981. It was originally intended that student groups would be able to locate and inventory local wetlands and have the data compiled in a notebook for future development planning. Contact Bill Eckel, King County Planning for further help, ideas cr information. (344-7990)

NAME ____________________

FIELD INVESTIGATION: Survey of the Wetland

CONCEPTS:

1. A map of a site is the first step in evaluating it.
2. A profile graph of the site shows changes in elevation with horizontal distance.
3. Mapping and profiling provide a data base to inventory, survey and analyze vegetation and animal life.

A. MAPPING THE WETLAND

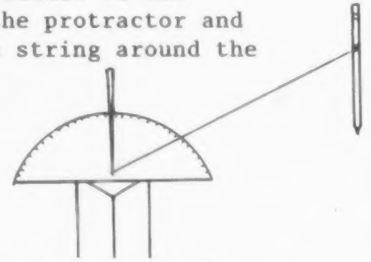
MATERIALS:

Protractor
5 foot tall stick
1 piece of string: 10 inches
1 nail
1 lab book
1 pencil
graph paper
ORCA Activity Packet - Beach Profiles and Transects
ORCA Activity Packet - Marine Biology Field Trip Sites

PROCEDURES:

1. Construct the siting tool. Put the nail through the center of the protractor and stick the nail into the top of the stick.

2. Tie one end of the string around the middle of the pencil. Leave enough space between the protractor and the stick to tie the other end of the string around the nail.
   The "tool" should appear this way:
   The string, pulled tight by the pencil becomes the sighting line for the instrument.



3. Now place yourself with the mapping tool in front of you. Pick a distant location point B and line up the protractor so the 90° line is in direct alignment. You are ready for your first sighting. On a blank paper, place a dot labeled B to represent where you are standing. Now place the dot labeled A on the paper in the direction that you have the protractor facing; it doesn't matter how far apart they are. Draw a line between the 2 marks. This is your baseline. Its orientation on the paper determines the orientation of your chart and its scale as the actual distance between point A and B is represented by your base line length.

NAME__________________________________

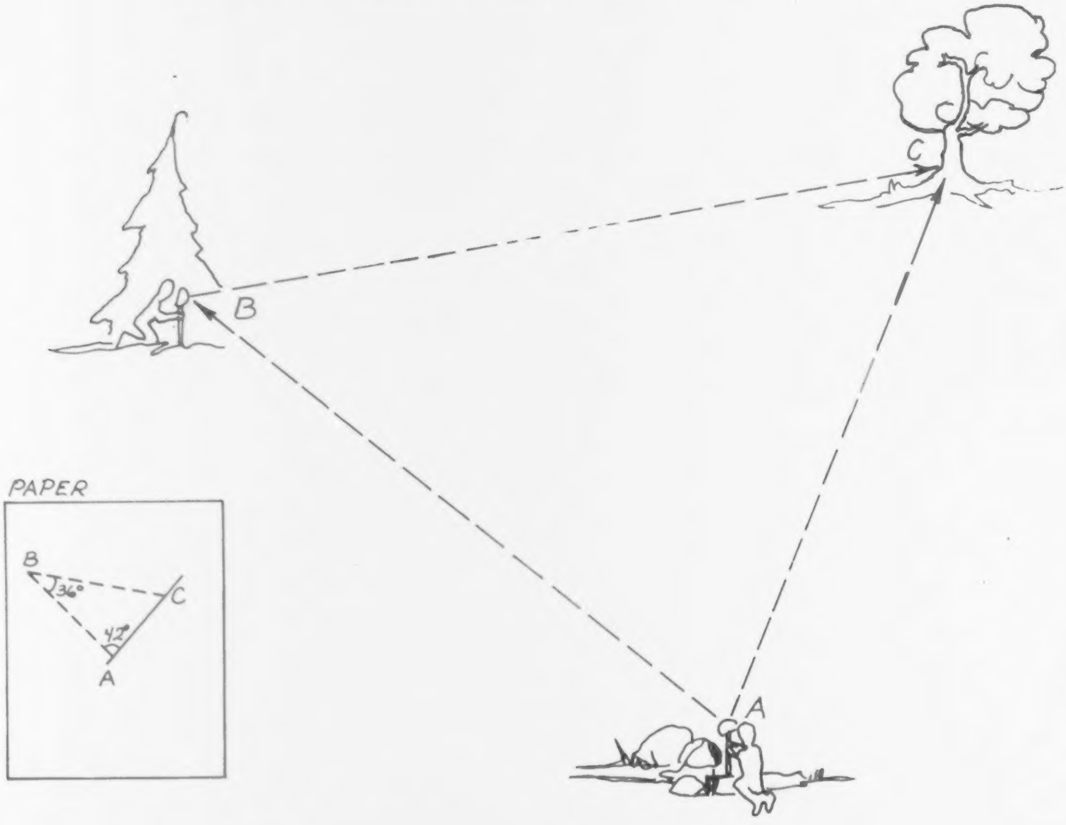
4. The next measurement is critical. Still facing the first sighting move the pencil/string to line up with a new object or location. As you look down at the protractor you can determine how many degrees the new site is from the baseline. Note this on your paper.

5. Put the center point of the protractor on Spot A. Line up the 90° center line with the A-B line on your paper. Draw a new line from point A along the degree mark you noted in the second sighting. It is not necessary to measure the specific distance. This will be determined by the next measurement.

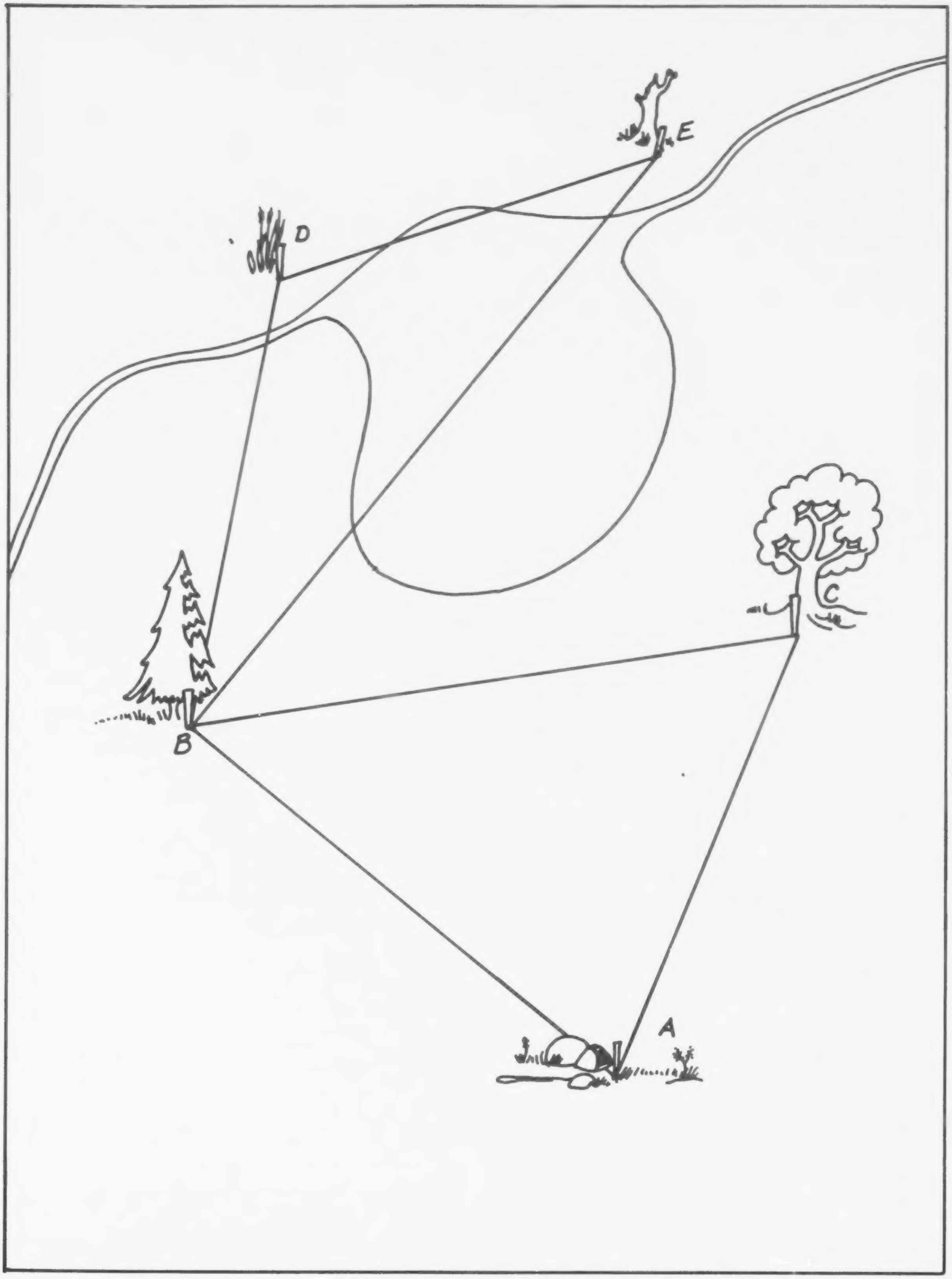
6. Now take your sighting device to the site you identified as B. Sight back to point A on the center 90° line. Then align the pencil/string with the third spot. Note the degrees.

7. On your paper repeat the previous instruction and draw the proper line from site B along the noted degree line to the third site.

8. Where the A-C line crosses the B-C line is the exact location of C relative to both A and B. You now have a mapped out an area in which all distances are to scale and proper orientation to each other. You may also determine where magnetic North is relative to your base line and indicate this on your map.



NAME________________________



NAME________________________

9. You can continue plotting points on your map by taking new sightings on different objects from points A and B. Or you can shift and use line A-C or B-C as a new baseline and reference point. With care a very accurate map can be produced. A check on the accuracy can be made by using two located points many steps removed from the original base line. Go to these points and determine where point A should be on the chart. Your derived point A location should fall right on top of the labeled point A if the work was done carefully.

   (See graphic next page)

10. Determine the scale by measuring one of the lines in the field and measuring the same length of the paper; so many feet: to so many inches.

NAME________________________

B. BEACH TRANSECT: A PROFILE

Do a transect of the 3 baselines. Follow the directions below or obtain copy of Beach Profiles and Transects for further directions and activities.

MATERIALS: For each team of three students:

pencil
clipboard or something to write on
2 meter sticks
sighting pole
range pole
level (optional)

PROCEDURES:

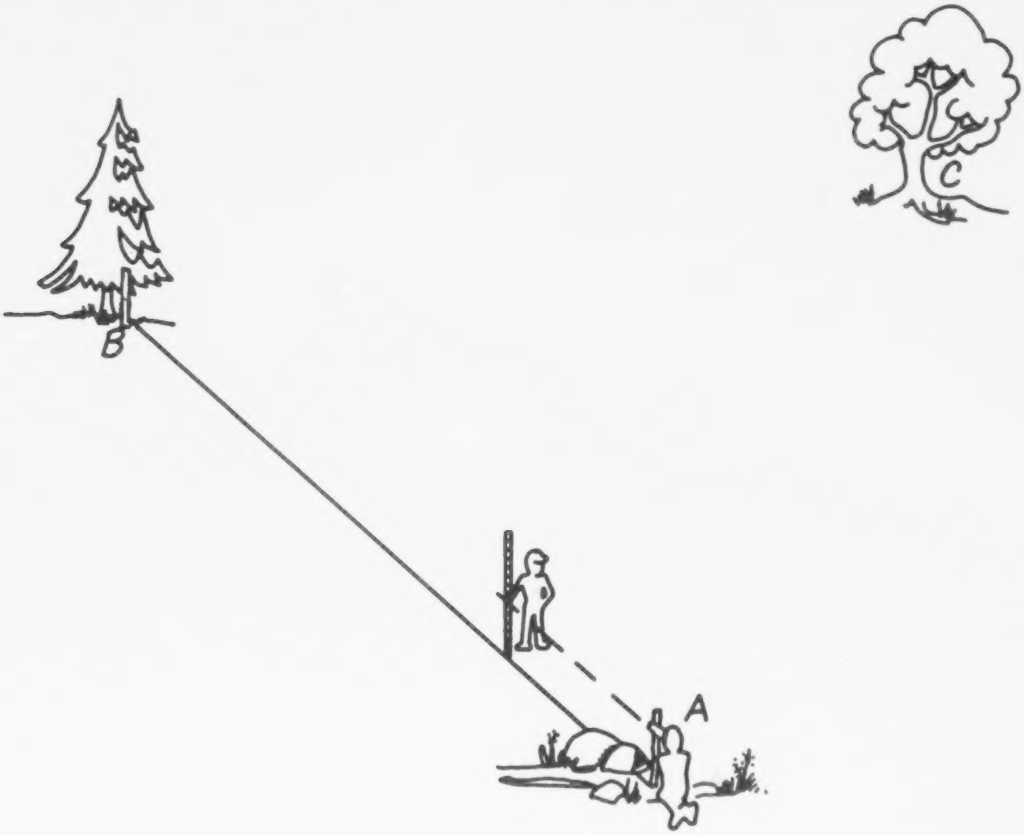
1. Your team will probably work most smoothly if:
   One person is the recorder, recording on the chart the range pole reading and the elevation difference given by the sighter. S/he also checks the plumbline to make sure the sighting pole is held vertically.

   One person is the sighter, making the sightings to determine the + or - elevation differences.

   And one person is the holder, holding the range pole upright so the sighter can make the sightings.

   These duties can be rotated so each member gets a chance to do each.
2. Stand at the Point A and look toward Point B.
3. Work will start at Point A. Sight to Point B and send one team member to Point B to drive a stake into the ground. This stake will be the goal point toward which the team will work.
4. The sighter, using the sighting poles, sights on the goal stake and drives his/her pole into the ground up to the guideline. Now the range pole holder stations him/herself 2 meters away from the sighter, between the sighter and the goal stake so that the sighter can see the range pole through the sighting device.
5. The recorder should check the plumb line on the sighting pole to make sure it is being held perfectly vertical. Adjust, if necessary.
6. The sighter, looking horizontally as determined by the plumb line through the nail hole and sighting through the cross hairs of the juice can, should instruct the range pole holder to move his/her hand up or down the pole until the hand is along the same line of sight as the cross hairs.

NAME________________________

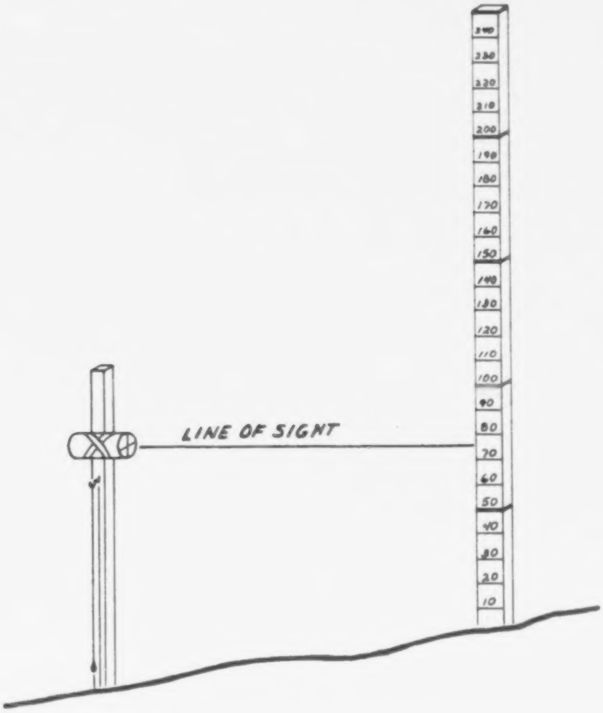


7. The recorder now records on the beach profile chart the range pole reading and the difference in ground elevation between the poles. This figure is obtained by subtracting the reading on the range pole from 100 centimeters. (100 cm = 1 meter = height of sighting device.) If the range pole is at a higher elevation, we get a positive (+) figure, if it is at a lower elevation, our difference is negative (-).

8. The sighter moves the sight pole to exactly the same spot where the range pole is placed and drives it in. The range pole now moves 2 meters closer to the goal stake. Repeat steps 3-6 until the goal stake is reached.

9. Once the elevation profile is constructed, observation using a quadrat could be made over the profile to determine how populations vary or substrate varies with elevation change or distance from the water's edge. In case this profile is constructed referring to tidal waters, a tide curve can be constructed for the day observations are made. The time can be used to establish how many feet your observed tide water level is above or below mean lower low water using this tide curve.

STUDENT WORKSHEET - TAKING READINGS

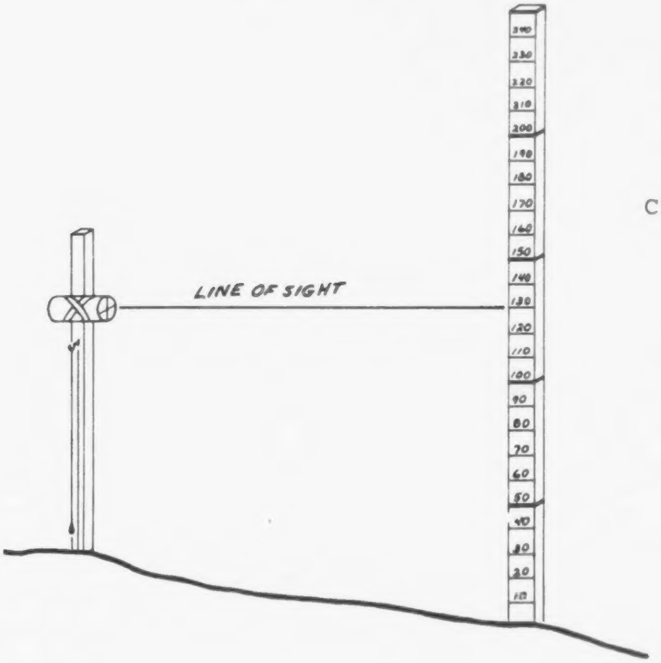

LINE OF SIGHT
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

B) What is the reading here?

____

What do you record on the chart?

____


LINE OF SIGHT
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

C) What is the reading?

____

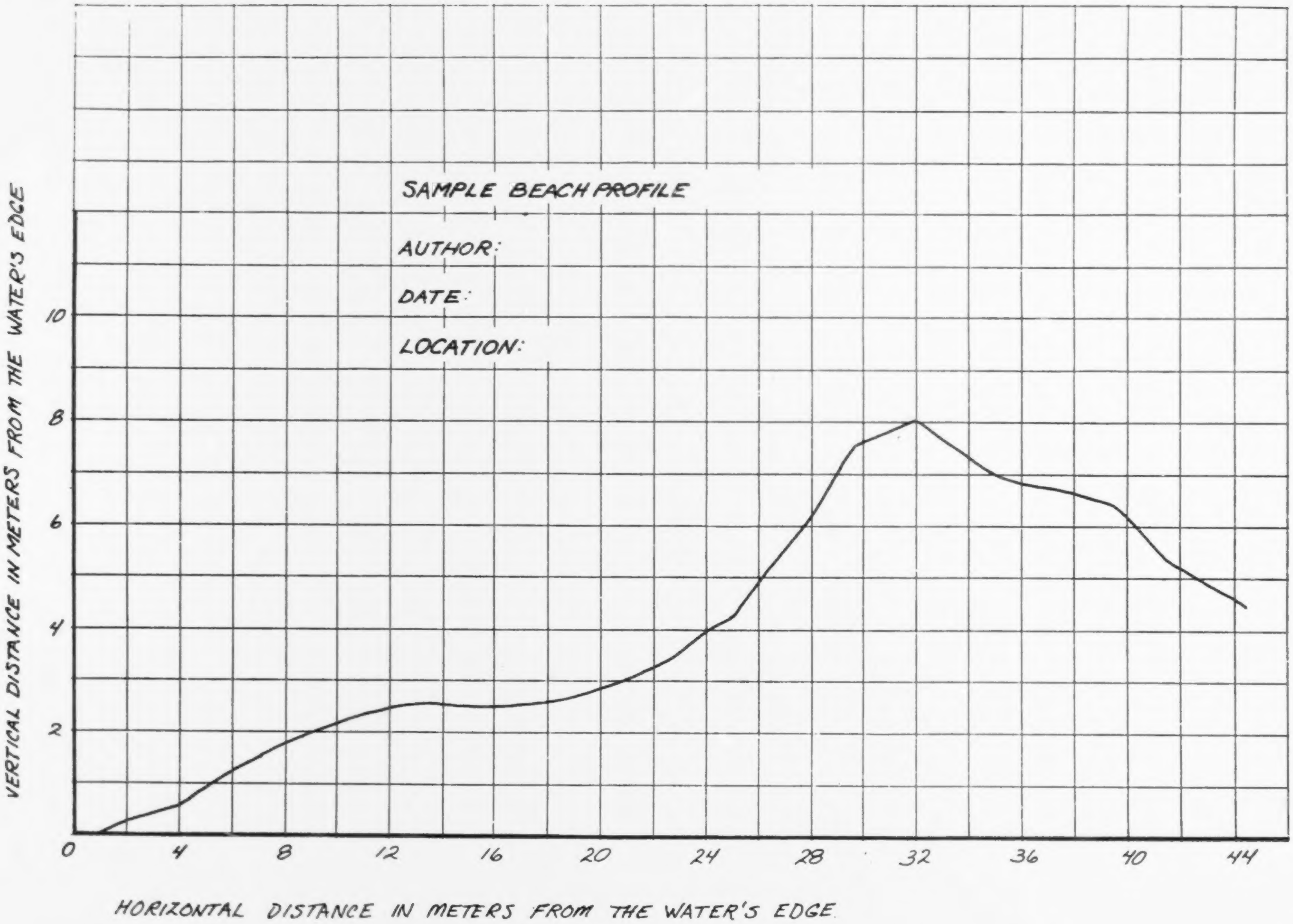
What do you record?

____

CHART FOR BEACH PROFILE READINGS

NAME________________________

READING #	Range Pole Reading	Elevation Difference + or -


SAMPLE BEACH PROFILE
AUTHOR:
DATE:
LOCATION:
VERTICAL DISTANCE IN METERS FROM THE WATER'S EDGE
10
8
6
4
2
0
4
8
12
16
20
24
28
32
36
40
44
HORIZONTAL DISTANCE IN METERS FROM THE WATER'S EDGE

NAME ____________________

FIELD INVESTIGATION: Vegetative Analysis

CONCEPTS:

1. Different species of plants and animals are found in different habitats, based on abiotic and biotic factors.
2. Plant communities can be analyzed and the relative importance of each species determined quantitatively.
3. This quantitative analysis helps determine the presence, abundance, frequency and dominance of each species.
4. Birds can be excellent subjects for ecological studies for many reasons:
    - They are common year round.
    - There are usually many species.
    - They have fascinating behavior patterns.
5. Animals are more difficult to spot, yet evidence of existence is often readily observed (seen, discovered)
6. Mapping and profiling a site provide a data base to inventory, survey and analyze vegetation and animal life.

MATERIALS:

- Quadrat - use a rigid square form for which the area is known. Coat hangers bent into shape are useful. The students can calculate the area.
- Field guides like:
    - "Wild Flowers of Marsh and Waterways" by Lewis Clark
    - "Wild Flowers of the Sea Coast" by Lewis Clark
    - "Wild Flowers of North America" by Audubon
    - "Wetland Plants of King County and Puget Sound Lowlands" by King County Planning Division

PROCEDURES:

1. You will be using a quadrat to sample and obtain quantitative information about the plants in a wetland per unit area of earth surface and will sample the study area at several sites. You will need to make several decisions about your sampling technique prior to starting. Your teacher can be helpful in making the decisions.

2. Determine the number of quadrat sites required to effectively sample the area. Note that number on the field data sheet. You should sample about 10% of the total area being studied. Therefore, if you have a small area, you may have as few as 10 samples. Larger areas of course will require more sample sites.

3. Determine the arrangement of the quadrats. Note this on the field data sheet.

    A. Random method. To be statistically valid, plots need to be scattered throughout the area randomly. One way is to close your eyes, turn around and toss the quadrat over your shoulder. Analyze the vegetation in the quadrat where it landed.

NAME________________________

B. Systematic method. This method uses quadrats that are spaced widely and evenly apart throughout the study area. Run a series of evenly spaced transects through the area. Place the quadrat at equal intervals along these lines. This is generally easier and better than random location and with fewer errors.

4. Determine the kind of information you want from within the quadrat boundaries:

   A. List quadrat - the plants within the frame are identified and listed by name. No count is made. Can calculate frequency.

   B. Count quadrat - the name and the number of each species is noted. Can calculate abundance and density.

   C. Cover quadrat - the percentage of land surface in the study area that is covered by a certain species. Can use this to calculate dominance.

5. Go to the study area, locate the quadrats, identify the species and record the data on the field data sheet. Make the appropriate calculations.

6. Optional. Locate the quadrats on the map constructed in the "Field Investigation: Survey of the Salt Marsh."

DOMINANCE AND FREQUENCY: Abundance and Density

These statistics are measurements of impact. Dominance is the relative amount of area covered by a species when viewed from above ground. In a given quadrat of vegetation, for instance, a large fir tree might be the dominant species simply because it covers most of the surface when viewed from above.

Frequency refers to how often the organism appears in the samplings. It need not be a dominant organism in terms of size.

A. FREQUENCY - $\dfrac{\text{\# of plots in which species occurs x 100}}{\text{total number of plots}} =$

B. RELATIVE FREQUENCY - $\dfrac{\text{frequency of a species}}{\text{total frequency all species x 100}} =$

Abundance compares the number of plants of that species with the total number of plants of all species in the study area.

NAME________________________

C. ABUNDANCE - $$\frac{\text{number of plants of a certain species}}{\text{total number of plants x 100}} =$$

Density is defined as the number of plants of a certain species per unit area. Relative density compares the density of a species with the total density for all species.

D. DENSITY - $$\frac{\text{number of plants of certain species}}{\text{total area sampled}} =$$

E. RELATIVE
DENSITY - $$\frac{\text{density of a species X 100}}{\text{total density for all species}} =$$

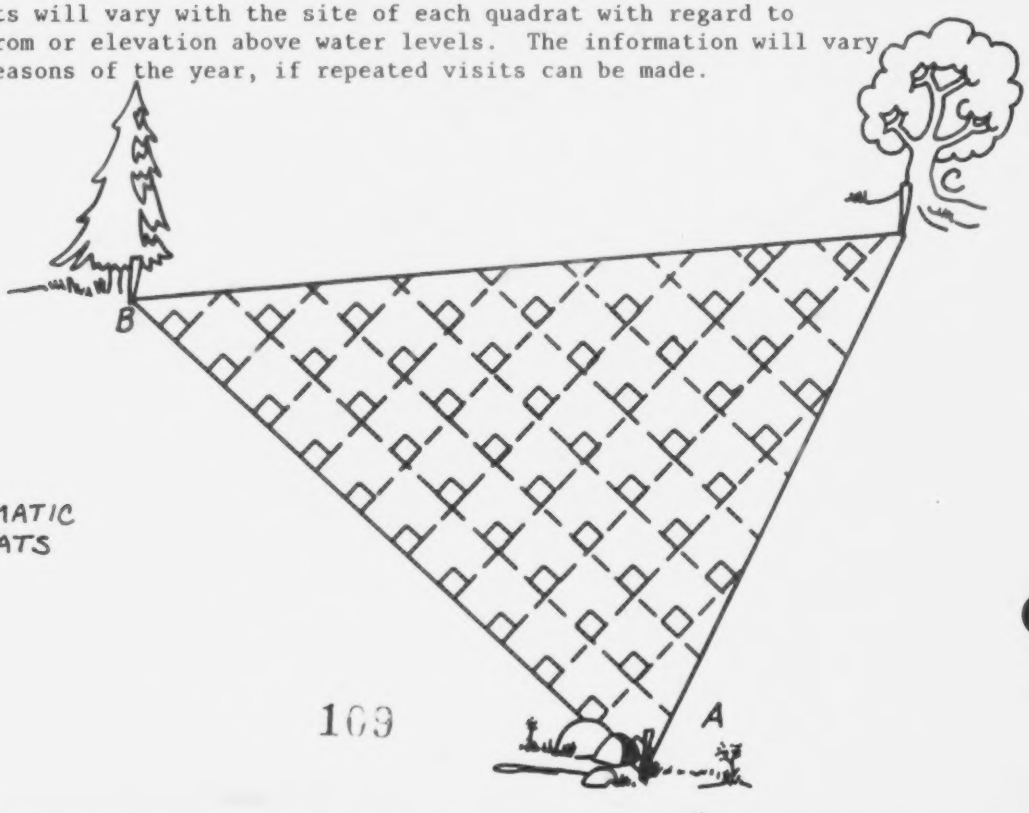
Dominance - (use this technique to determine how much of the surface area the organism covers when viewed from above):

F. DOMINANCE -

% area covered		statistical number
0 - 5%	=	1
5 - 25%	=	2
25 - 75%	=	3
75 - 95%	=	4
95 - 100%	=	5

$$\frac{\text{totals of statistical numbers}}{\text{total area sampled}}$$

Note: Measurements will vary with the site of each quadrat with regard to distance from or elevation above water levels. The information will vary over the seasons of the year, if repeated visits can be made.



SYSTEMATIC
QUADRATS

NAME____________________

FIELD DATA SHEET: Vegetative Analysis

SITE____________________________

TEAM____________________________

SKETCH OF AREA:

NUMBER OF QUADRATS SAMPLED______

ARRANGEMENT OF QUADRATS: (Circle One)

RANDOM SYSTEMATIC

INFORMATION YOU WANT: (Circle One(s))

FREQUENCY

ABUNDANCE

DENSITY

DOMINANCE

DATA COLLECTION:

Quadrat Number	List of Plants Found	Number of Individuals of Each Species	Percent of Area Covered (Dominance)

NAME____________________

DATA COLLECTION:

Quadrat Number	List of Plants Found	Number of Individuals of Each Species	Percent of Area Covered (Dominance)

(Duplicate this page as needed)

NAME__________________

FIELD DATA SHEET: Vegetative Analysis Summary

Plant Species:	Number of plots in which species occurs	Total number of individual plants	% of area covered
	Total number of plots	Total number of all plants	

NAME ____________________

FIELD INVESTIGATION: Bird and Animal Sightings

CONCEPTS:

1. Wetlands are important habitats for many species of birds and animals.
2. Birds are excellent subjects for ecological studies for many reasons, including: they are common year round, usually many species, and fascinating behavior patterns.
3. Animals are more difficult to spot, yet evidence of existence is often readily found.

MATERIALS:

Binoculars
Field guides for birds like Audubon's Guide to North American Birds
Map of the area

PROCEDURES:

1. Use the map of the area. Make a grid across the area by evenly spacing markers on the map that correspond to locations noted in the field.

2. Along the line of markers have a pair of students walk and observe birds and/or animals. Use your binoculars as necessary.

3. If a bird or animal is sighted, identify the species and note it along with the nearest location point on the map grid. Record the information along with observations about the habitat, its location in the habitat (i.e. upper limb of tree) sex, manner of location, food, feeding method, vocalizations, general behavior, nature of evidence.

4. Following this activity compile the data and discuss observations.

NAME____________________

FIELD DATA SHEET: Bird and Animal Sightings

Species	Habitat	Location in Habitat	Sex	Feeding Method	Food

Duplicate pages as needed

NAME______________________

FIELD DATA SHEET: Bird and Animal Sightings

Species (con't)	Vocalization	Behavior	Nature of Evidence

Duplicate pages as needed

NAME ____________________

FIELD INVESTIGATION: Chemical/Physical Analysis

CONCEPTS:

1. Abiotic factors such as the amount of dissolved oxygen, temperature, pH, salinity, nutrients influence the habitat and types of plants and animals.

MATERIALS:

Several Hach water test kits (obtain from scientific supply houses)
Hach soil test kits
(or LaMotte Water & Soil test kits)
Field Data Sheet
Thermometers
Optional: included in these procedures are the chemical tests for water. The Hach kits are often easier and sometimes less expensive to use to conduct the same tests.

PROCEDURES:

1. Select locations on the map to conduct the chemical and physical analysis.
2. In pairs, go to the locations, note them on the map and do the tests.
3. Record the data and any pertinent observations.
4. In class, use the data to evaluate the wetland in terms of value function and impact. Included in the teacher/student information sheets is a chart of organisms that indicate a range of tolerance for the abiotic factors such as oxygen, pH and temperature.

Teacher/Student Information Sheet

NAME ____________________

Dissoved Oxygen in Water

Oxygen is produced by plants as a by-product of photosynthesis. The amount of dissolved oxygen in the water is related to the amount of mixing of water and air and the temperature of the water. Aquatic animals are dependent on the dissolved oxygen. Some animals require a high concentration of dissolved oxygen, others can tolerate an environment of low or even non-existent oxygen levels. Oxygen can dissolve out of water fairly quickly, therefore in testing for dissolved oxygen it is important to combine the O_2 with other chemicals to stabilize it for accurate results. In this test, after adding the chemicals, one Iodine molecule exists for each molecule of O_2. By using starch as an indicator the parts per million of O_2 can be calculated.

MATERIALS:

250 ml collecting bottle with stopper
.9 M alkaline iodide solution
3.2 M manganous sulfate
concentrated sulfuric acid
.025 M sodium thiosulfate
starch
500 ml flask
pipet
3 dropper bottles, each dropper with 1 ml graduations.

PROCEDURES:

1. Lower the 250 ml collecting bottle beneath the surface of the water. Let it overflow and stopper it while still underwater. Avoid trapping bubbles.

2. Remove the stopper. Add 1 ml of the manganous sulfate, with the end of the dropper held below the water surface level.

3. In the same way add 1 ml of alkaline iodide solution. Be very careful.

4. Stopper the bottle. Mix the solution. Allow the precipitate to settle. The top 1/3 of the solution will be clear.

5. Repeat the procedures by adding 1 ml of manganous sulfate and 1 ml alkaline iodide and mixing as before.

6. In the lab add 1 ml concentrated sulfuric acid by letting it run down the neck of the bottle. Sulfuric acid is very caustic. Be extremely careful and cautious.

7. Stopper. Mix well. Let sit for 10 minutes, until the precipitate dissolves.

8. Using 200 ml of the treated water, put sample in a 500 ml flask.

9. Measure out 10 ml of sodium thiosulfate. Using a medicine dropper add it to the water solution one drop at a time until the solution is pale yellow. (Straw color).

10. Add 3 ml of starch. The solution will become blue in color.

11. In the final step, add sodium thiosulfate drop by drop. Mix the solution continuously. When the blue color disappears, stop. (The blue may return).

12. Record the amount of sodium thiosulfate used. One ml of sodium thiosulfate is equivalent to two parts per million oxygen. Calculate the parts per million of oxygen.

Teacher/Student Information Sheet

NAME ____________________

Carbon Dioxide in Water

Carbon dioxide is a natural by-product of animal respiration. It is an important compound for plants which use CO_2 in the photosynthetic process. Carbon dioxide can result from the decaying process and can also be found dissolved in water from the air. Carbon dioxide dissolved in water forms weak carbonic acid. Sodium hydroxide is a base which can neutralize the acid. Phenalphthalein is an indicator which turns from colorless to red when the pH of a solution is 10 or more. One mole of CO_2 reacts with one mole of Sodium Hydroxide. In the test 1 ml of Sodium Hydroxide is equivalent to 1 mg of CO_2 which is equal to 1 part per million of CO_2.

MATERIALS:

50 ml of sample water
50 ml beaker
Phenolphthalein
Sodium hydroxide solution (.023 M)
graduated cylinder

PROCEDURES:

1. Measure 50 ml of sample water into a beaker. Add 2 drops of the indicator phenotphthalein. Note color.

2. Measure 10 ml of sodium hydroxide into a graduated cylinder. Add the sodium hydroxide drop by drop into the water until it turns pink and stays pink after stirring.

3. Record the amount of sodium hydroxide used.

4. Calculate the amount of CO_2 in the water sample. Remember, each ml of sodium hydroxide is equivalent to 1 mg of CO_2. Each mg equals 1 p.p.m. of CO_2.

Teacher/Student Information Sheet

NAME ____________________

Plant and Animal Indicators of Water Quality*

Indicators for acid pollution:

	O_2	Temp	pH	Clarity of Water
Arrowhead		10 - 25°c	6.5 - 7.5	clear
Water lily		10 - 25°c	6 - 10	clear
Elodea		10 - 25°c	6 - 10	clear
Cattail		10 - 25°c	6 - 10	clear to murky
Euglena		10 - 25°c	2 - 10	clear to murky

Indicators for Oxygen:

	O_2	Temp	pH	Clarity of Water
Rainbow trout	6.5 ppm	5 - 20°c	6.5 - 8	clear
Crayfish	4.0 ppm	10 - 25°c	6 - 9	clear to murky
Frogs	2.0	5 - 30°c	6 - 9	murky
Carp	.5	5 - 30°c	6 - 9	murky
Pond Snail	2.0	10 - 25°c	7 - 9	murky
Leech	2.0	10 - 25°c	6 - 9	murky

These plants and animals are found in freshwater environments. Organisms living in the water can be useful indicators of certain qualities of water. Perhaps the most critical factor is dissolved oxygen. This chart includes the outside ranges of tolerance. In considering the plants and animals as indicators also bear in mind the size, depth, quantity of water. Also consider relative population sizes.

---

* After charts in Investigating Our Ecosystem by Irma Greisel and Peter Jensch.

NAME____________________

FIELD DATA SHEET: Chemical/Physical Analysis

Sample Location	Observations (appearance, smells, etc.)	pH	O_2	CO_2	Optional Water Tests:		
					Salinity	Phosphates	Nitrates

Duplicate extra pages as needed

NAME ____________________

Wetlands Inventory

The Wetlands Inventory form helps to determine the type, function and importance of any given wetland. Each section emphasizes specific functions of the wetland. Information collected in the field investigations will be useful. Use the previous activities for background information for this inventory.

Type of Wetland (check)

____ A. Palustrine

____ 1. marsh

____ 2. swamp

____ 3. bog

____ 4. pond

____ B. Lacustrine

____ 1. large lake

____ 2. small lake

____ C. Riverine

____ 1. stream

____ 2. river

____ D. Estuarine

Hydrology (check)

A. Determine the location of the outlet to the wetland.

- ____ 1. No outlet is apparent.
- ____ 2. Outlet is overland and is a defined exit.
- ____ 3. Outlet is overland; water flows over the edge.
- ____ 4. Outlet is a defined channel.
- ____ 5. Outlet is a pipe.

B. Determine the condition of the outlet.

- ____ 1. Outlet is open.
- ____ 2. Outlet is partially blocked.
- ____ 3. Outlet is totally blocked.

C. Water flowing out of the wetland enters:

- ____ 1. stream
- ____ 2. river

NAME____________________

____ 3. lake

____ 4. wetland (marsh, swamp, bog, pond)

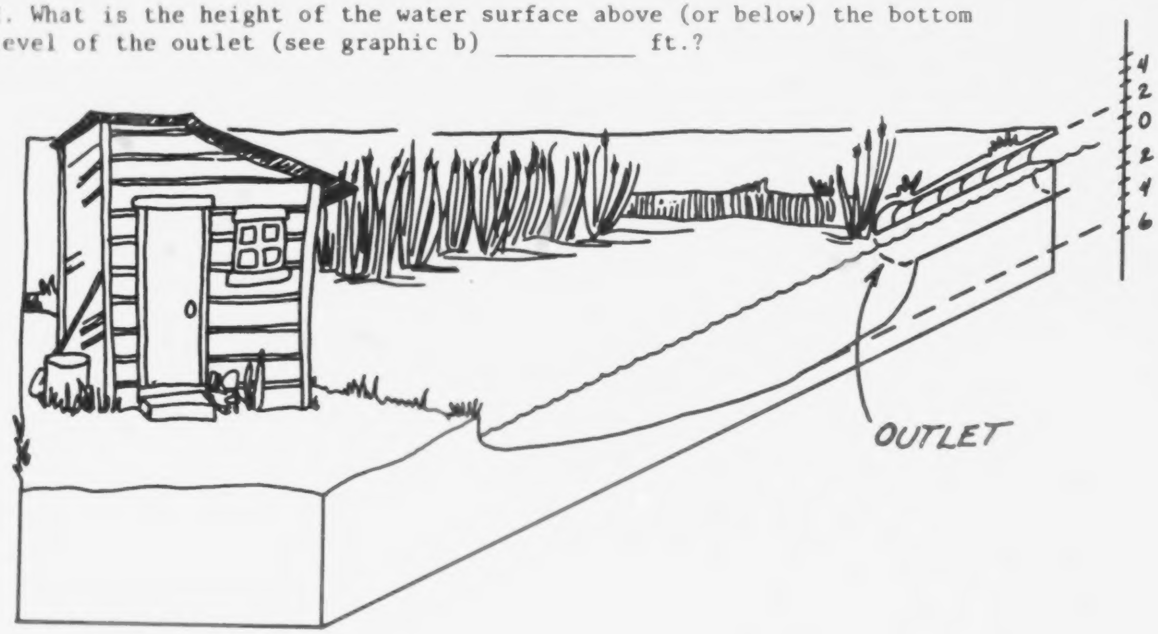
____ 5. Puget Sound

____ 6. pipe

D. Consider the flood control potential.

1. What is the height of the point of flooding above the bottom level of the outlet (see graphic a) __________ ft.?

2. What is the height of the water surface above (or below) the bottom level of the outlet (see graphic b) __________ ft.?



E. Determine the degree of water movement through the wetland:

____ 1. Standing water

____ 2. No visible movement (but water is moving through the outlet)

____ 3. Visible movement of water through the wetland

F. Determine the extent of pollutant discharge into the wetland:

____ 1. No known discharges

____ 2. Probable discharge from __________.

____ 3. Visible discharge from __________.

NAME________________________

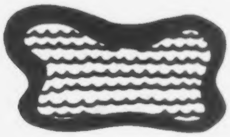
Vegetation and Wildlife

A. Determine the presence of plant and animal species. (List.)

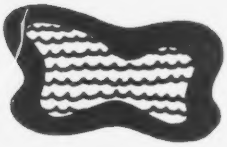
NAME____________________

B. Determine the degree of vegetative cover on the wetland (as viewed from above.)

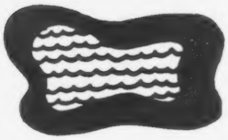
____ 1. 0 - 5% coverage



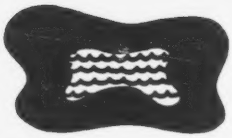
____ 2. 5 - 25% coverage



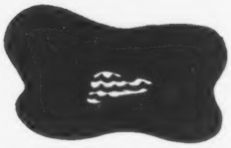
____ 3. 25 - 75% coverage



____ 4. 75 - 95% coverage



____ 5. 95 - 100% coverage



NAME____________________

C. Determine the surrounding habitat/land use. (Check all appropriate items. Sketch wetland and surrounding area.)

____ 1. water

____ 2. grass

____ 3. woods

____ 4. brush/shrubs

____ 5. agriculture

____ 6. urban - high density

____ 7. suburban - low density

D. Determine special habitat features.

____ 1. snags over 18" in diameter; greater than 25 feet high

____ 2. snags over 18" in diameter; less than 25' high

____ 3. snags less than 18" in diameter; greater than 25' high

____ 4. snags less than 18" in diameter; less than 25' high

____ 5. rock outcrop

____ 6. perches

____ 7. logs

____ 8. beaver and/or muskrat lodges

____ 9. other ______________

Visual, Cultural, Economic, Educational

A. Determine the distance to nearby schools/colleges.

1. Elementary school __________ miles

2. Junior High school __________ miles

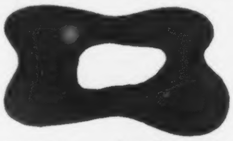
NAME__________________________

3. Senior High school __________ miles

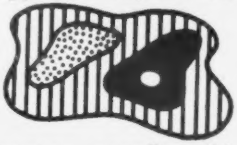
4. College or University __________ miles

B. Determine the visual diversity of vegetation. Which figure best represents the number and distribution of vegetative types?

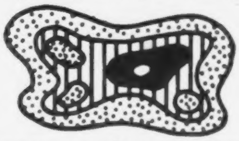
____ 1. Minimal vegetative types; simple distribution



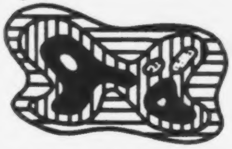
____ 2. Several vegetative types; simple distribution



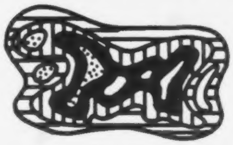
____ 3. Several vegetative types; complex distribution



____ 4. Many vegetative types; complex distribution

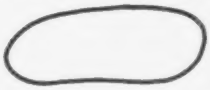


____ 5. Many vegetative types; extremely complex distribution

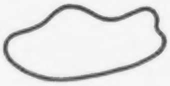


C. Determine the shape of the wetland edge. The range is from a new straight edge to a very complex, convoluted edge.

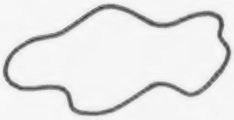
____ 1.



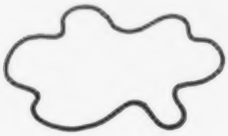
____ 2.



____ 3.



____ 4.



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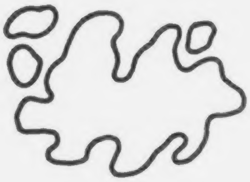
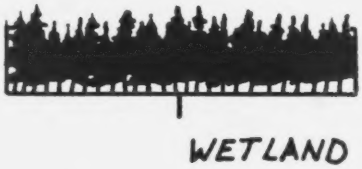
____ 5.



D. Determine the visual differences between the height of the vegetation on the wetland and the height of the surrounding vegetation.

_____1.



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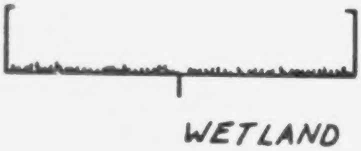
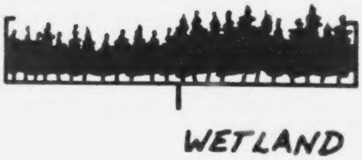


_____2.



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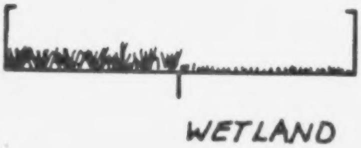
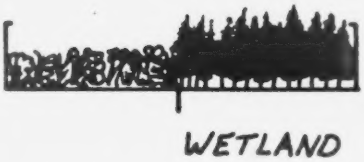


_____3.



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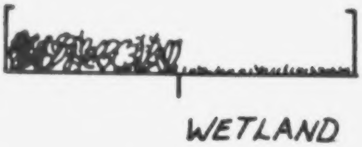
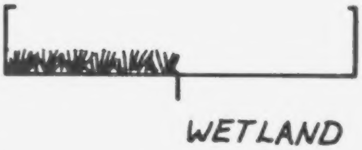


_____4.



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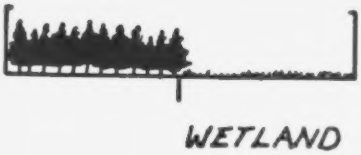
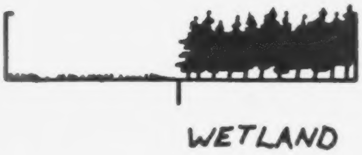


_____5.



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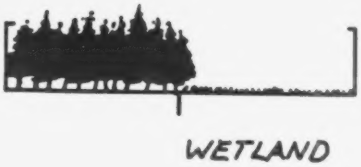


NAME________________________

E. Determine the different types of land forms visible from the wetlands.

____ 1. cliff or bluff

____ 2. mountain(s) or ridge

____ 3. hill or hilly area

____ 4. valley

____ 5. canyon

____ 6. flat, level plain

____ 7. other __________

F. Determine the different types of water bodies associated with the wetland.

____ 1. lake

____ 2. reservoir

____ 3. pond

____ 4. river

____ 5. stream

G. Indicate different types of access to the wetland.

____ 1. trail

____ 2. road

____ 3. boat on associated river/stream

____ 4. boat on associated lake/reservoir

H. Indicate different types of access on the wetland.

____ 1. trail

____ 2. road

____ 3. boat

I. Indicate and describe types of environmental problems observed on or near the wetland.

____ 1. visual

____ 2. air

____ 3. noise

____ 4. water

NAME____________________

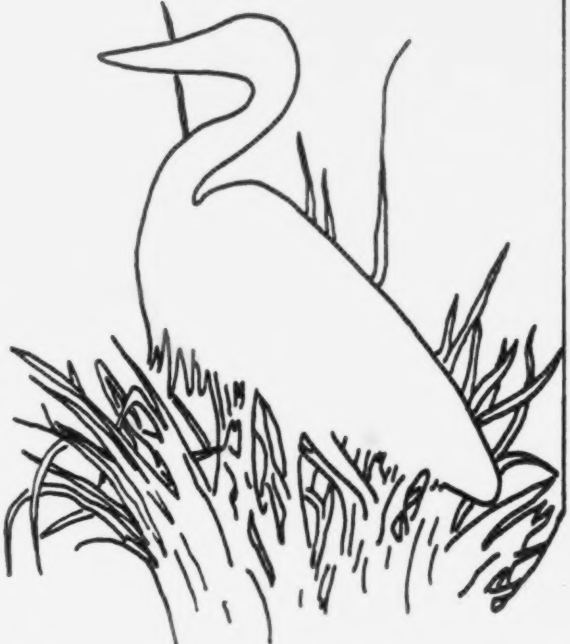
J. In your opinion is the wetland one that should be:

____ 1. preserved at all costs as a protected wetland

____ 2. kept within a developed area with a buffer zone of ____ feet.

____ 3. drained or filled for future construction/development needs.

K. Explain your rationale for the above decision.



EVALUATION, VOCABULARY, BIBLIOGRAPHY

Teacher Information

EVALUATION

Part 1 - Watersheds and Wetlands Systems

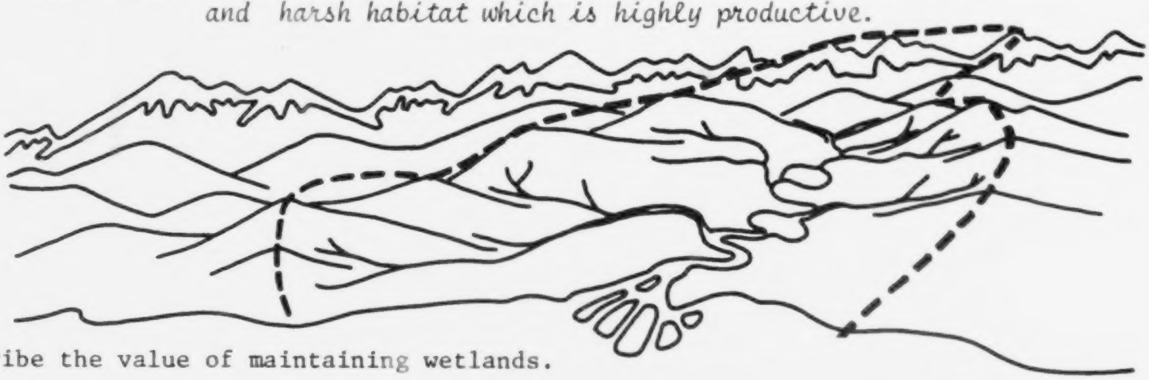
1. What are wetlands?

Wetlands are special habitats where the soil has become wet or even saturated by water that is either standing or flowing through. Because of the constantly wet conditions this environment is home for special plants and animals that need those conditions to live. They are fragile and subject to alteration by humans who frequently drain the water away. There are four classifications of wetlands: palustrine, lacustrine, riverine and estuarine.

2. Describe a watershed. Include a description of the wetland components. (You might wish to include a diagram.)

A watershed is a 'catch' basin in which all precipitation that falls gradually flows together into a major river which enters into the sea (or sound.) The basin is defined geographically and the perimeter is usually formed by a mountain range (or at least elevated highlands.) Within the watershed are major components, in and of themselves, special habitats. They are:

palustrine - A wetland in upland areas which have open water areas but no definable edges. Four different habitats are represented, including, freshwater marshes, bogs, swamps and ponds.
lacustrine - Lakes. Areas with large open water areas which have definable edges.
riverine - Rivers. A fast flowing watersystem.
estuarine - A wetland area where fresh and salt water meets. A special and harsh habitat which is highly productive.



3. Describe the value of maintaining wetlands.

Wetlands are special habitats with conditions that are necessary for the survival of certain species of plants and animals. Destruction of wetlands by draining, dredging, and filling in would result in the loss of these species. Wetlands also store water during periods of heavy rain and slowly release it later, thus preventing flooding downstream.

Part 2 - Estuaries and Salt Marshes

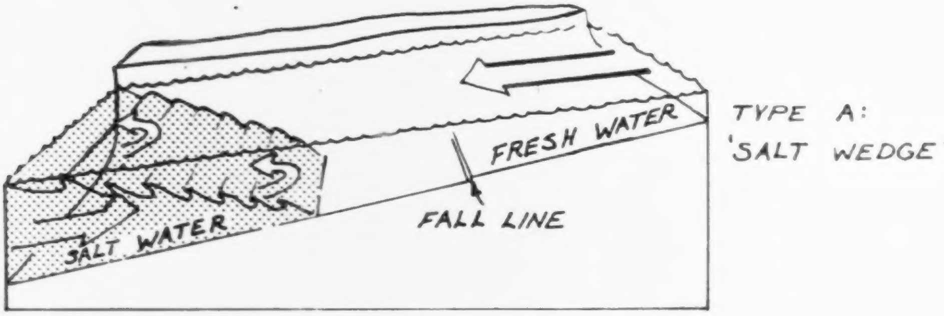
1. Describe the estuarine environment.

The estuary is a place where the salt water from the ocean meets the fresh water flowing out from the rivers. Generally this is a semi-enclosed basin. This habitat is highly productive and is considered the nursery grounds for many species.

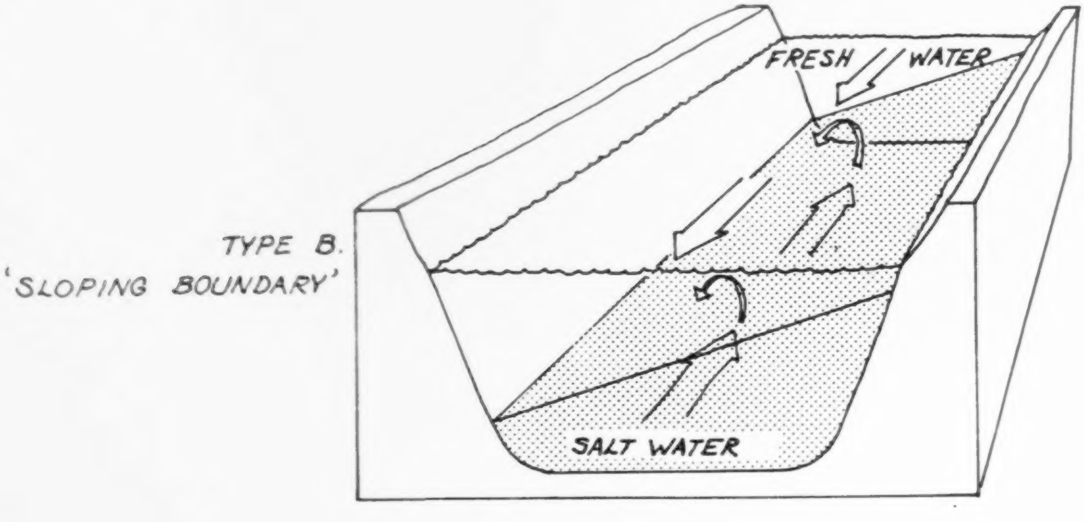
Teacher Information

2. Describe the differences between the four types of estuaries: (diagrams are optional)

Type A - The Salt Wedge: *a typical pattern that is formed when the incoming salt water, which is denser than fresh water, tries to flow in along the bottom of the basin. The out going fresh water, being less dense, flows out the mouth of the river, with sufficient force to push the salt water back and override it at the surface.*

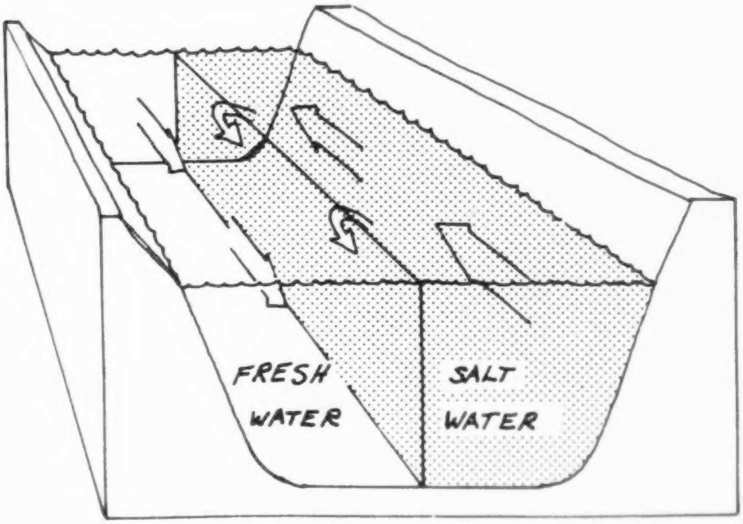

FRESH WATER
FALL LINE
SALT WATER
TYPE A:
'SALT WEDGE'

Type B - Sloping Boundary: *by adding a little more turbulence from the tidal currents relative to the river flow the mixing is greater. The fresh water tends to flow outward along the right side of the river bank, while the salt water hugs the left bank.*


FRESH WATER
TYPE B.
'SLOPING BOUNDARY'
SALT WATER

Teacher Information

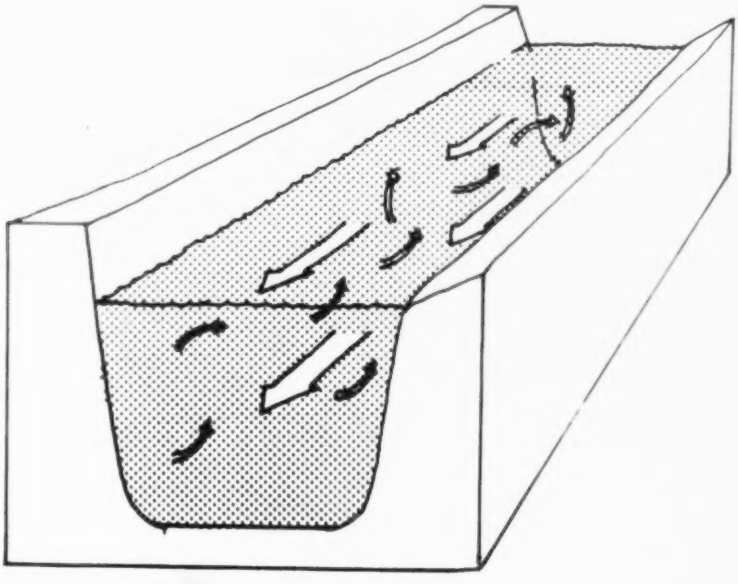
Type C - Vertical Boundary: *occurs when the amount of tidal currents and mixing increases even more relative to the amount of fresh water flow. The greater turbulence mixes the water vertically. The south bank facing seaward tends to be of higher salinity concentration than the north.*



TYPE C
VERTICAL BOUNDARY

Type D - Well Mixed: *extreme turbulence causes the salinity of the water to be fairly uniform from top to bottom and cross channel. Such turbulence is caused by large tidal currents.*

TYPE D
"WELL MIXED"



Teacher Information

3. Describe what is meant by the 'flushing' of Puget Sound.

   This process is aptly named. Puget Sound, over the course of a year, gets rid of water that has been in the basin and brings in water from the Pacific Ocean to replace it. The new ocean water is rich in nutrients and fosters the highly productive biological growth in Puget Sound. This is an extremely complex process and is necessary for the revitalization of the sound.

4. Diagram a typical food web found in the salt marsh-estuary.

   (see the diagram from Activity 2 as an example)

Part 3 - Field Investigation and Wetland Inventory

1. Explain the difference between the random and systematic methods of sampling.

   The random sampling allows plots to be scattered over the area and findings from the samples are generalized to the whole area. The systematic samples cover more of the area, are evenly spaced and are generally easier and have fewer errors than the random method.

2. Define:

   Frequency - *refers to how often the organism appears in the samplings.*

   Abundance - *compares the number of plants of that species with the total number of plants of all species in the study area.*

   Density - *is defined as the number of plants of a certain species per unit area.*

   Dominance - *a perception of the surface area an organism covers when viewed from above.*

NAME________________________

EVALUATION

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3. Describe the value of maintaining wetlands.

Part 2 - Estuaries and Salt Marshes

1. Describe the estuarine environment.

NAME________________________

2. Describe the differences between the four types of estuaries: (diagrams are optional)

Type A - The Salt Wedge:

Type B - Sloping Boundary:

NAME____________________

Type C - Vertical Boundary:

Type D - Well Mixed:

NAME________________________

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   Abundance -

   Density -

   Dominance -

VOCABULARY

Palustrine - wetlands in upland areas which have open water areas but no definable edges. Four different habitats are represented: freshwater marshes, bogs, swamps and ponds.

Lacustrine - wetlands commonly called lakes. Areas with large open water areas which have definable edges.

Riverine - a river wetland. They are fast flowing watersystems.

Estuary - a wetland area where fresh and salt water meets. A special and harsh environment which is highly productive. Generally has five major classifications according to how they were formed: Drowned River Valley, Coastal Shelf Estuary, Fault Bays, Fjords, and Narrow River Mouths. Also classified by type and amount of salt and fresh water mixing.

wetland - an environment where soils are wet or water saturated. They are characterized by plants that are water tolerant. They are important for their water retention ability.

eutrophic - the build up of nutrients and minerals in a lake or pond resulting in a decrease in oxygen available for animals. It is part of the aging process of wetlands.

oligotrophic - the state of newly formed lakes or ponds that have few nutrients to sustain life.

aquifer - subterranean water systems, also called ground water.

hydrologic cycle - the cycling of water from precipitation to the ground and runoff into rivers and subsequently into the ocean. In the ocean the water is evaporated by solar radiation, ultimately forming clouds which results in precipitation over land.

watershed - an ecological unit, defined by the geography of a basin, whereby all precipitation and runoff flows together in a watercourse to the sea.

NAME________________________

VOCABULARY

Palustrine

Lacustrine

Riverine

Estuary

wetland

eutrophic

oligotrophic

aquifer

hydrologic cycle

watershed

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